Historische en hedendaagse systeem-innovaties in de glastuinbouw en varkenshouderij:
Een innovatie-sociologische analyse

Eindrapport voor het Transforum project: 'Historical and future transitions in agriculture and food'

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Voorwoord

Dit rapport vormt de eindrapportage van het onderzoek dat verricht is in het kader van het project 'Historical and future transitions in agriculture and food'. Dit project is gefinancierd door Transforum Agro en Groen (TAG), en uitgevoerd door onderzoekers van de Technische Universiteit Eindhoven (Technologie Management) en Wageningen Universiteit en Researchcentrum (Communicatie en innovatiestudies). Wij danken TAG voor het faciliteren en ondersteunen van het onderzoek.

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Inhoudsopgave

1. Inleiding

1.1. Onderzoeksobject: Transities en systeeminnovaties

Transities en systeem-innovaties in de landbouw zijn het thema van dit rapport. Klimaatverandering, energiegebruik, methaan-emissies, dierenwelzijn, economische concurrentie, voedselschandalen (BSE, dioxine), verzuring, stankproblemen, landschapsinrichting, en rurale ontwikkeling zijn enkele van de socio-economische ontwikkelingen die druk creëren op het landbouw-systeem. Veel van deze ontwikkelingen kunnen (waarschijnlijk) niet binnen de grenzen van het bestaande systeem het hoofd geboden worden. Daarom is het thema van transities naar nieuwe systemen (systeem-innovatie) gestegen op de maatschappelijke en politieke agenda. Dit heeft geleid tot nieuwe beleidsplannen, zoals het NMP-4 (Vierde Nationaal MilieuBeleidsPlan) en innovatie-programma's, bijvoorbeeld ICES-KIS waar duurzame systeem-innovaties een van de thema's is (waarbinnen Transforum een van de gesubsidieerde programma's is).

De theoretische achtergrond van ons onderzoek is innovatie-sociologie, waarbij we dus focussen op de actoren en hun gecontextualiseerde interacties in systeem-innovaties. In onze socio-technische benadering, zien we transities en systeem-innovaties als multi-dimensionele processen, die we conceptualiseren als veranderingen in: 1) technologieën (systemen, componenten), 2) actoren en sociale netwerken (allianties, samenwerkingsverbanden, marktrelaties), en 3) regime regels, waarbij we onderscheid maken tussen cognitieve regels (routines, belief systems, guiding principles, vuistregels), normatieve regels (rollen, gedragsnormen), en regulatieve regels (wetten, standaarden, emissie-eisen). In navolging van Giddens (1984), worden deze regels voortdurend gereproduceerd door actoren in concrete handelingspraktijken en netwerken.

Wat betreft empirische focus gaat dit rapport over transities in twee sectoren: glastuinbouw en varkenshouderij. Voor beide sectoren doen we een studie van historische transities en een studie van contemporaine transities ‘in the making’. Hedentendaage, staat de glastuinbouw onder druk wegens hoog energiegebruik (en dus CO_2 emissies en klimaatverandering), vooral gerelateerd aan ruimteverwarming met gas. De varkenssector staat onder druk wat betreft dierenwelzijn (o.a. ruimtegebruik in stallen, onverdoofd castreren van biggetjes), internationale economische concurrentie, en mestproblematiek (verzuring, stank). In reactie op deze druk, zijn in beide sectoren radicale innovatietrajecten gestart die systeemcomponenten aanzienlijk veranderen. Twee hoofdstukken in dit rapport gaan over dergelijke innovaties:

1) **Energie uit de kas**. Wat betreft de glastuinbouw worden projecten rond 'energie uit de kas', bestudeerd; hierbij wordt warmte opgevangen tijdens de zomermaanden en via warmtewisselaars naar ondergrondse acquifers overgebracht. In de wintermaanden wordt deze warmte dan weer opgepompt om kassen te verwarmen. Deze innovatie kan het gasverbruik, en dus de CO2 emissies in de glastuinbouw, aanzienlijk verminderen, en wellicht zelfs energie produceren (om mogelijk ook woonwijken mee te verwarmen).
2) **Dierenwelzijn en varkensstallen**. Wat betreft de varkenshouderij worden nieuwe stalconcepten onderzocht, met name op de dimensie van beschikbare ruimte en dierenwelzijn.

Deze innovatietrajecten vormen 'niches', waarin zich kiemen voor systeeminnovaties kunnen ontwikkelen door de inspanningen, netwerken, en leerprocessen van groepen actoren. Het verdere doorbreken van deze niche-innovaties, en dus het realiseren van transities, hangt echter af van interacties met ontwikkelingen op bredere regime- en landschapniveaus. Om dergelijke interacties beter te begrijpen presenteert het rapport ook de bevindingen van twee analyses van historische transities:

3) **Mechanisering in glastuinbouw (1930-1980).** Dit betrof een transitie van deels open kassen ('Westland kas'), waar glasplaten verwijderd konden worden om regens binnen te laten, naar geheel gesloten kassen ('Venlo kas') met kunstmatige verwarming, belichting, besproeiing en irrigatie.
4) **de transitie van gemengd boerenbedrijf naar bio-industrie (1930-1970).**

In deze historische cases kunnen we *hele* transities bestuderen (van begin tot eind), en conclusies trekken over kenmerkende patronen in regime transformatie.

Een verdere theoretische reden voor deze case-selectie bouwt voort op een analytisch onderscheid dat Poole en Van de Ven (1988) maken. Zij stellen dat proces theorieën twee complementerende componenten moeten hebben: 'global' and 'local' models, in onze woorden een 'outside in' analyse (die focust op overall patronen) en een 'inside out' analyse (die focust op hoe actoren hun weg zoeken, navigeren, onderhandelen, strijden etc.):

> "The global (macro, long-run) model depicts the overall course of development of an innovation and its influences, while the local (micro, short-run) model depicts the immediate action processes that create short-run developmental patterns. (...) A global model takes as its unit of analysis the overall trajectories, paths, phases, or stages in the development of an innovation, whereas a local model focuses on the micro ideas, decisions, actions or events of particular developmental episodes" (p. 643).

De twee historische cases, die *hele* transities bestuderen, zijn 'global' of 'outside in' analyses, terwijl de twee contemporaine cases 'local' of 'inside out' analyses maken.

1.2. Vraagstelling

De onderzoeksvragen voor de historische cases zijn:

- Hoe verliepen deze transities?
- Welke patronen en mechanismen waren belangrijk in deze transities?

De algemene onderzoeksvraag voor de twee hedendaagse cases is: Hoe dragen interacties en ontwikkelingen op micro niveau bij aan het in gang zetten van transitie processen? Voor de beide casussen is dat als volgt verder gespecificeerd:

- Varkenscasus: Hoe draagt de koppeling van normatieve druk met andere processen bij aan het uitlokken van verschillende transitiepaden?
- Glastuinbouwcasus: Hoe dragen koppelingen tussen niche- en regimeontwikkeling bij aan het in gang zetten van transitie processen?

1.3. Algemeen socio-technisch perspectief op transities

Onze disciplinaire achtergronden zijn innovatie studies en techniek-sociologie (MacKenzie and Wajcman, 1985; Bijker *et al.*, 1987; Rip, 1995). Innovatie wordt hierin geanalyseerd als socio-technisch proces, hetgeen in algemene zin betekent dat de analyse zich richt op:

- co-evolutie van technologie en maatschappij: aan de ene kant, hebben technische innovaties invloed op maatschappelijke ontwikkelingen (bv. voedselpatronen, economische ontwikkelingen); aan de andere kant, heeft de maatschappelijke context invloed op technische ontwikkelingen (bv. via subsidies, regelgeving, probleemagenda's).
- technologische innovatie als sociaal proces; het is 'enacted' door actoren; verschillende typen actoren hebben invloed op technische innovatie, bv. bedrijven, universiteiten, beleidsmakers, maatschappelijke groeperingen, gebruikers. Innovatie kan worden bestudeerd als de uitkomst van interacties tussen deze groepen.
- technologische innovatie als multi-dimensioneel proces. Hierbij spelen (bedrijfs)economische overwegingen een rol (bv. cost-benefit overwegingen bij investeringsbeslissingen, concurrentie tussen bedrijven), maar ook sociale netweken (bv. kennisflows tussen universiteiten en bedrijven, strategische coalities), politieke beslissingen en macht (regelgeving, lobbyen), en culturele aspecten (bv. discourses, symbolen, culturele normen, maatschappelijke acceptatie).

Voor de analyse van transities en systeem-innovaties gebruiken we twee specifiekere perspectieven, die beide binnen de socio-technische traditie staan: 1) Strategisch Niche Management (SNM), dat vooral kijkt naar de dynamiek *binnen* innovatie-niches, 2) het multi-level perspectief (MLP), dat vooral geschikt is om *hele* transities te analyseren, en dat kijkt naar interacties tussen niche, regime en landschap.

<u>Strategisch niche management (SNM)</u>

Strategisch niche management is een combinatie van technieksociologie en evolutionaire economie. Het evolutionaire aspect zit onder andere in het idee dat radicale innovaties ontstaan in 'niches'. Dit idee is geïnspireerd door *biologische* evolutie, waar nieuwe soorten ook ontstaan in afgescheiden niches (zogenaamde alleopatrische speciatie). Schot en Geels (2007: 612) vatten dit idee als volgt samen:

> "In biology, most biologists accept that new species do not only emerge through adaptation, but usually also involve some form of isolation. In the allopatric theory developed by Ernst Mayr and others, new species emerge in geographically isolated niches or in niches operating at the periphery of a dominant existing ecosystem. These niches form the habitat for small populations that become isolated from their parental group at the periphery of the ancestral range. These niches lead to new developments because they provide a set of distinct selection pressures and thus lead to a divergent evolutionary path. Biological speciation in these small isolated populations may be rapid by evolutionary standards, because favorable genetic variation can spread quickly. In large central populations, on the other hand, favorable variations spread very slowly or change may be steadfastly resisted by the well-adapted population. Furthermore, when rare variants mix in large populations, the effect of the mutations may be watered down. So change in large populations tends to be small, directed to meet the requirements of slowly altering climates. Major genetic reorganizations, however, almost always take place in small peripherally isolated populations that can grow into a new species (see Mayr, 1963)."

Biologische evolutie-ideeën kunnen niet zomaar op het sociale domein worden toegepast, omdat er aanzienlijke verschillen zijn tussen natuur en maatschappij: a) variaties/mutaties zijn niet 'blind', maar 'intentioneel'; mensen hebben namelijk percepties, verwachtingen, en motieven, die beslissingen en investeringen in innovaties beïnvloeden; b) leren speelt een belangrijke rol in sociale evolutie, die dus meer Lamarckiaans dan Darwinistisch[1]; c) variatie en selectieomgeving zijn niet strikt gescheiden; actoren anticiperen op selectie (via verwachtingen en percepties) en proberen actief de selectieomgeving te beïnvloeden (bv. via marketing of lobbyen om stimulerende regelgeving en subsidies).

Biologische evolutie-noties moeten dus gesociologiseerd worden om ze toepasbaar te maken voor het bestuderen van technologische innovatie. Dat is wat Strategisch Niche Management (SNM) doet. Hoewel SNM ook management-implicaties heeft, gebruiken wij het vooral als een analytisch perspectief. Wat betreft het basisidee van 'isolatie' duidt een 'niche' op een beschermde ruimte. Voor radicale innovaties gaat het onder andere om bescherming tegen directe marktselectie. Dergelijk bescherming is nodig omdat dergelijke innovaties aanvankelijk vaak een lage prijs/performance ratio hebben, en dus moeilijk op met bestaande technologieën kunnen concurreren:

> “most inventions are relatively crude and inefficient at the date when they are first recognized as constituting a new invention. They are, of necessity, badly adapted to many of the ultimate uses to which they will eventually be put.”(Rosenberg, 1976: 195).

Maar bescherming heeft ook een sociologische component. Radicale innovaties wijken per definitie af van bestaande praktijken en regels in het regime, die worden gedragen en gereproduceerd door actoren in de bestaande populatie (groep, sector, industrie). Het bestaande regime heeft een bepaalde inertie en neiging tot reproductie (zie ook hieronder). Stabiliserende mechanismen leiden tot 'lock-in' en padafhankelijkheid (Arthur, 1989; Unruh, 2000; Walker, 2000). Daarom worden radicale innovaties aanvankelijk als 'vreemd' en 'afwijkend' bestempeld, wat leidt tot lage legitimiteit. Schumpeter, de aartsvader van de evolutionaire economie, onderkende al dat radicale innovaties te kampen hadden met dergelijke sociale en cognitieve barrières:

> “Thought turns again and again into the accustomed track even if it has become unsuitable. (...) The very nature of fixed habits in thinking, their energy-saving function, is founded upon the fact that they have become subconscious (...). But precisely because of this they become drag chains when they have outlived their usefulness. So it is also in the economic world. In the breast of one who wishes to do something new, the forces of habit rise up and bear witness against the embryonic project. (...) The reaction of the social environment against one who wishes to do something new, may manifest itself first of all in the existence of legal or political impediments. (...) Any deviating conduct by a member of a social group is condemned. (...) Even a mere astonishment at the deviation (...) exercises a pressure on the individual” (Schumpeter, 1934: 86-87).

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[1] In de biologie debatteerden Darwin en Lamarck over de retentiemechanismen in evolutie (erfbaarheid, 'inheritance'). Lamarck suggereerde dat organismen aangeleerde eigenschappen of kenmerken konden doorgeven aan hun nageslacht. Volgens Darwin kon dit niet. Pas met de ontdekking van DNA en de genetische revolutie heeft men in het midden van de 20[e] eeuw meer inzicht gekregen in de evolutionaire retentiemechanismen. Dit inzichten sloten beter aan bij Darwin dan bij Lamarck.

Afwijkingen van het bestaande (radicale innovaties) vinden dus zelden in mainstream populaties (regime-actoren) plaats. De creatie van nieuwe paden wordt wel aangeduid als een proces van 'mindful deviation' (Garud and Karnøe, 2001): er wordt afgeweken van bestaande routines en regels; dit afwijken wordt gedaan door menselijke actoren (entrepreneurs) die percepties, motieven, en verwachtingen hebben. SNM voegt hieraan nog toe dat de 'deviation' plaatsvind in niches, beschermde ruimtes waar afwijking wordt gefaciliteerd door bepaalde beschermingsmaatregelen. Die bescherming kan direct komen van subsidies en sociale netwerken (actoren die voor een bepaalde innovatie lobbyen en deze verdedigen in debatten); maar ook gedeelde verwachtingen geven, in meer abstracte zin, bescherming aan innovaties.[2] Als een verwachting breed gedeeld wordt, wordt de legitimiteit van bepaalde innovaties hoger, wat weer leidt tot meer interesse, grotere sociale netwerken, en meer subsidies. Als verwachtingen echter verzwakken (bijvoorbeeld door negatieve leerervaringen) kan dit bepaalde innovaties ondermijnen.

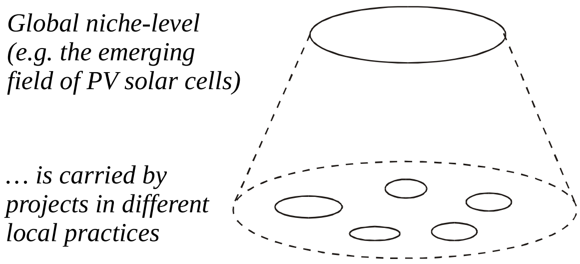
Op basis van deze overwegingen, onderscheidt SNM drie basisprocessen die belangrijk zijn bij de ontwikkeling van niche-innovaties (Kemp *et al*., 1998; Hoogma *et al*., 2002; Raven, 2005):

1. de vorming van *sociale netwerken*, die de niche-ontwikkeling dragen en erin investeren, en die bereid zijn de innovatie te verdedigen.
2. de articulatie, onderhoud, en aanpassing van *verwachtingen* en visies; enerzijds geven deze verwachtingen richting aan leerprocessen (en dienen ook te worden aangepast op basis van uitkomsten van leerprocessen); anderzijds dienen verwachtingen om andere actoren te interesseren (meer subsidies van beleidsmakers, andere bedrijven die mee gaan doen).
3. leerprocessen; innovaties worden verbeterd door technische leerprocessen (bv. R&D); maar leerprocessen kunnen ook betrekking hebben op de markt (wat willen gebruikers), regelgeving (hoe moeten bestaande regels worden aangepast), infrastructuur, en culturele aspecten (welke metaforen worden gebruikt? hoe verloopt maatschappelijke acceptatie).

Hieronder geven we nader aan hoe deze processen op elkaar inwerken, alsmede de rol van experimenten en demonstratieprojecten. Zoals hierboven is aangegeven, zijn variatie- en selectieomgeving in sociale evolutie niet strikt gescheiden. Experimentele projecten zijn een derde koppelingsmechanisme, naast verwachtingen en bewust beïnvloeden van de selectieomgeving. Dergelijke projecten vormen plekken waar variatie- en selectie vroegtijdig bij elkaar worden gebracht. Het zijn 'proto-markten' waar radicale innovaties selectief kunnen worden bloot gesteld aan selectiedruk. Omdat het in een beschermde omgeving plaatsvindt, gaat deze selectie niet om wel/niet overleven, maar om leren en netwerkbouw. De feedback van gebruikers, maatschappelijke groepen, en andere selectie-actoren wordt gebruikt om de innovaties te verbeteren, en daarna opnieuw bloot te stellen aan selectiedruk. Innovatietrajecten komen dus tot stand door een sequentieel proces van 'probe and learn' (Lynn *et al*., 1996).

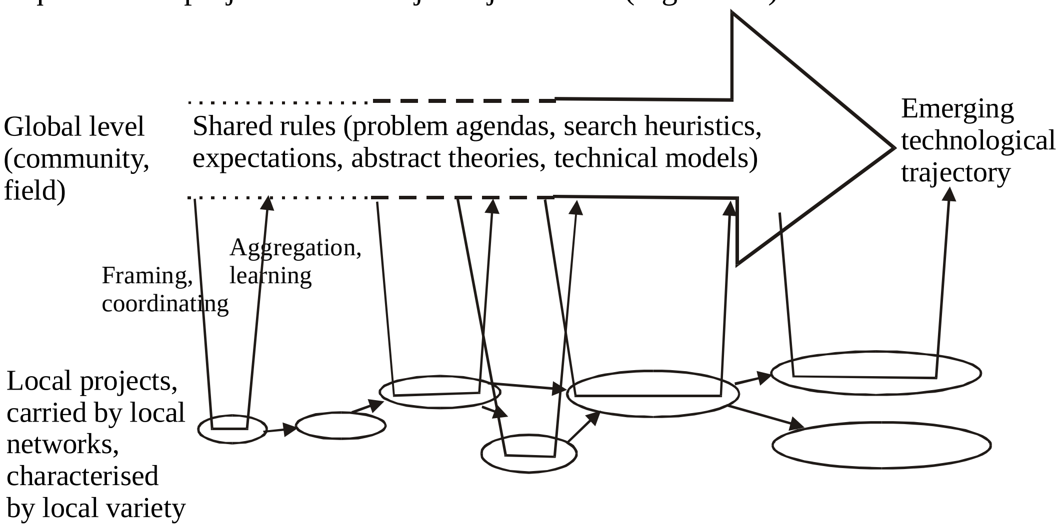
SNM-onderzoekers maken een onderscheid tussen lokale projecten en de algemene niche. De niche van biologische varkensteelt (of zonne-cellen) wordt bijvoorbeeld gedragen door verschillende lokale projecten (Figuur 1.1).

[2] Verwachtingen over de 'hydrogen economy' helpen nu bijvoorbeeld mee om niches voor brandstofcellen, waterstofbussen en waterstof-auto's te creëren.



Figuur 1.1. Lokale projecten projecten en een globaal[3] niche niveau (Geels en Raven, 2006: 378)

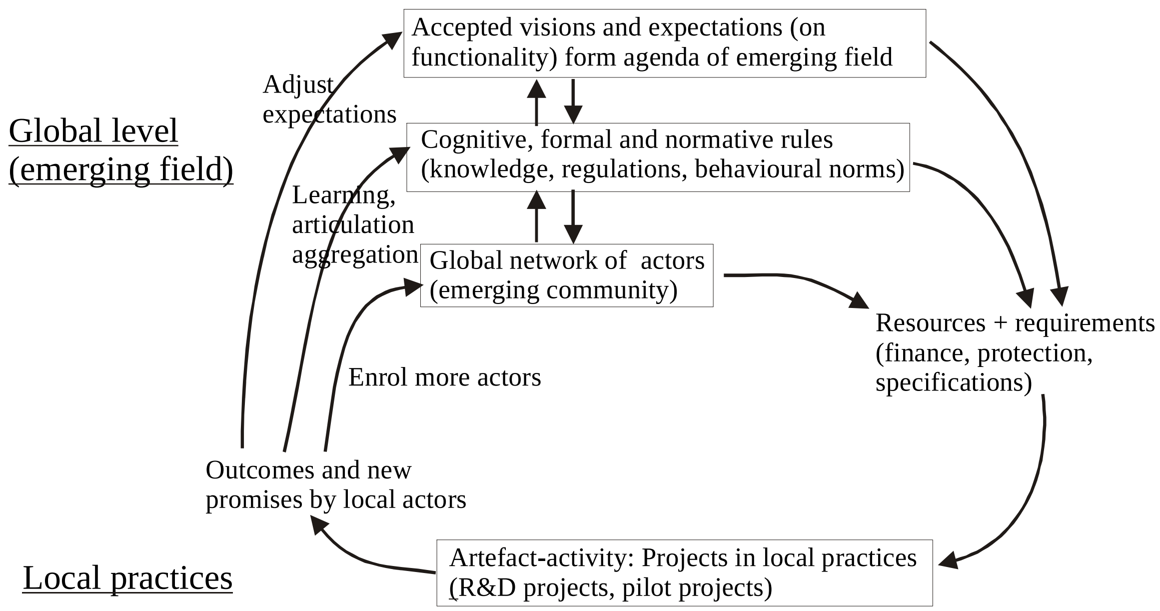
Het niche niveau bestaat uit een sociaal netwerk (een 'emerging community'), die bepaalde regels delen. Dat zijn cognitieve regels (verwachtingen, probleemagenda's, zoekheuristieken), normatieve regels (rolpatronen, gedragsrelaties) en formele regels (bv. wet- en regelgeving, standaarden). Als een niche net ontstaat zijn deze gedeelde regels vaak diffuus, vaag, onduidelijk, niet gearticuleerd. Sequenties van projecten kunnen vervolgens optellen tot innovatietrajecten waarin geleerd wordt over de niche-innovatie, en waardoor de regels gaandeweg stabieler kunnen worden. Als we aannemen dat een project ongeveer 2-3 jaar duurt, dan kan stabilisering door een sequentie van projecten makkelijk 10 jaar duren (Figuur 1.2).



Figuur 1.2. Niche ontwikkelingstraject, gedragen door lokale projecten (Geels and Raven, 2006: 379)

Voor succesvolle niche-ontwikkeling zijn positieve interacties nodig tussen de drie interne niche processen: a) sociale netwerken die innovatie dragen, b) leerprocessen over techniek, gebruikerspreferenties, regelgeving, infrastructuur, etc. c) ontwikkelen en bijstellen van verwachtingen en visies. Figuur 1.3 geeft schematisch weer hoe deze processen op elkaar inwerken en de rol van lokale projecten daarin.

[3] De term 'globaal' duidt hier niet op 'mondiaal', maar op een sociologisch onderscheid tussen lokale praktijken en kosmopoliete structuren die worden gedragen door een hele community rond een bepaalde innovatie.



Figuur 1.3. De sociale dynamiek van niche ontwikkelingstrajecten (Geels and Raven, 2006: 379)

Niche-ontwikkelingstrajecten zijn geen automatische processen: interacties tussen niche-processen vergen vaak speciale aandacht en het optellen van lokale projecten tot een breder innovatietraject vereist een bepaalde schaal, continuïteit, en zorg dat leerervaringen uit het ene project worden meegenomen in het volgende project. Als er te weinig projecten zijn en als ze te geïsoleerd van elkaar verlopen, wordt niche-ontwikkeling te weinig robuust en krijgt te weinig momentum.

In de hedendaagse innovatietrajecten in de glastuinbouw en varkenshouderij hebben de afgelopen jaren meerdere systeem-innovatieve projecten plaatsgevonden. Met behulp van het SNM-perspectief wordt de dynamiek in deze innovatietrajecten verder geanalyseerd.

Multi-level perspectief (MLP)

Niche-innovaties zijn belangrijk omdat ze de kiemen voor transities verschaffen. Maar voor de analyse van *hele* transities is het onvoldoende om alleen naar niche-innovaties te kijken. Men loopt dan namelijk het risico op technology-push benaderingen, met suggesties dat transities worden gedreven door niche-innovaties die na hun 'pre-development' een logische S-curve volgen; dit kan al snel leiden tot teleologie en determinisme (bv. sequenties van fasen die noodzakelijk op elkaar volgen).

Hoewel niche-innovaties belangrijk zijn voor transities, leggen wij daarom ook juist nadruk op de bredere sociaal-maatschappelijke omgeving. De 'vruchtbaarheid' van deze grond bepaalt mede of kiemen tot wasdom komen:

> “Macro-inventions are seeds sown by individual inventors in a social soil. (...) The environment into which the seeds are sown is, of course, the main determinant of whether they will sprout” (Mokyr 1990, 299).

Het zogenaamde multi-level perspectief (MLP) vertaalt deze seeds-soil metafoor middels de notie van 'windows of opportunity' die kansen bieden voor de bredere diffusie van niche-innovaties. Het MLP heeft dus ook deels een evolutionair karakter, in de zin dat niche-innovaties kunnen worden gezien als variaties, maar dat de doorbraak en maatschappelijke selectie van deze variaties afhangt van koppelingen met dynamieken op bredere regime en landschapsniveaus.

Net als SNM is het MLP een combinatie van inzichten uit de techniek-sociologie en evolutionaire economie. Het MLP onderscheidt drie niveaus: technologische niches, socio-technisch regime, en socio-technisch landschap. De niche-dynamiek is hierboven beschreven. Het regime begrip komt uit de evolutionaire economie en is later verrijkt met inzichten uit institutionele theorie. Nelson en Winter (1982) introduceerden het begrip 'technologisch regime' in de evolutionaire economie om het bestaan van 'technologische trajecten' te verklaren. Nelson en Winter observeerden aan de hand van casestudies dat de probleemoplossingactiviteiten van ingenieurs relatief stabiel waren en niet altijd in de pas liepen met de markt. Ingenieurs richtten zich op bepaalde problemen en werden geleid door bepaalde noties over oplossingsrichtingen. Een regime bestaat dus uit cognitieve regels en noties die gedeeld worden door ingenieurs. Op basis van hun casestudie naar het DC-3 vliegtuig in de jaren ’30 schrijven Nelson en Winter de stabiele richting van ontwikkeling toe aan cognitieve noties. Ingenieurs hadden welontwikkelde ideeën omtrent het potentieel van het design (van metalen body, zuigermotor en lage vleugels). Voor meer dan 20 jaar was innovatie in vliegtuigontwerp gericht op de benutting van dat potentieel, via verbetering van motoren, vergroting van het vliegtuig en grotere zuinigheid. De technologie ontwikkelde zich dus in een afgebakende richting, hetgeen leidde tot een technisch traject.

Nelson en Winter leggen dus de nadruk op cognitieve regels en routines in de hoofden van ingenieurs, die werden gedeeld in technische gemeenschappen. Rip en Kemp (1998) hebben deze opvatting van technologisch regime meer sociologisch gemaakt, door nadruk te leggen 'regels' die breder verankerd zijn:

> “A technological regime is the rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artefacts and persons, ways of defining problems; all of them embedded in institutions and infrastructures” (Rip and Kemp, 1998: 340).

Omdat deze definitie vooral focust op technologie (met name de ontwikkeling), is het niet direct geschikt voor transities waar het gaat om veranderingen in bredere socio-technische systemen. Geels (2004) heeft daarom het begrip 'socio-technisch regime' geïntroduceerd, dat op twee manieren breder is. Ten eerste worden socio-technische regimes gedragen door meerdere sociale groepen, niet alleen ingenieurs en bedrijven, maar ook gebruikers, beleidsmakers, lobbygroepen etc. Ten tweede worden op navolging van institutionele theorie (Scott, 1995), drie typen regels onderscheiden (cognitieve, regulatieve, normatieve), met bepaalde sociale mechanismen (Tabel 1.1).

	Regulative	**Normative**	**Cognitive**
Examples	Laws, regulations, standards, procedures, incentive structures, governance systems.	Values, norms, role expectations, duty, codes of conduct, behavioural practice, identity	Belief systems, models of reality, bodies of knowledge, guiding principles, search heuristics
Basis of compliance	Expedience	Social obligation	Taken for granted
Mechanisms	Coercive (force, punishments)	Normative pressure (social sanctions such as	Mimetic, learning, imitation

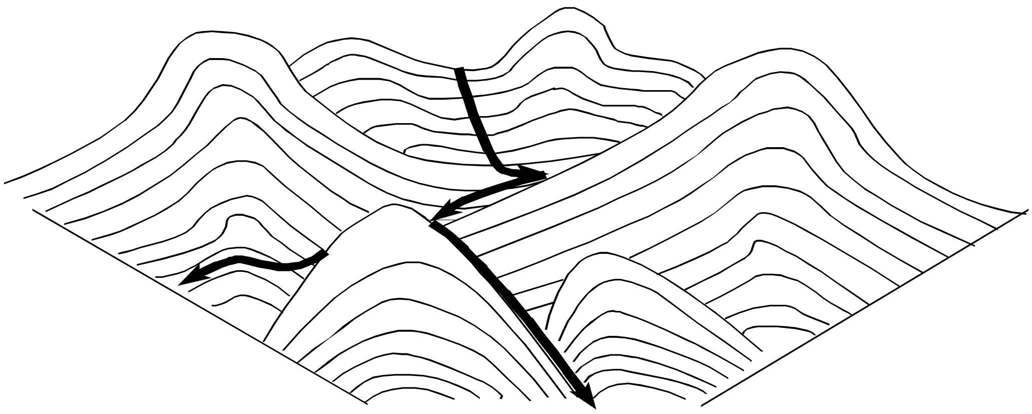
		'shaming')	
Logic	Instrumentality (creating stability, 'rules of the game')	Appropriateness, becoming part of the group ('how we do things')	Orthodoxy (shared ideas, concepts)
Basis of legitimacy	Legally sanctioned	Morally governed	Culturally supported, conceptually correct

Tabel 1.1. Drie typen regels en sociale mechanismen (Scott, 1995: 35, 52)

Deze regels dragen op verschillende manieren bij aan de stabiliteit van bestaande sociotechnische regimes. *Cognitieve* routines kunnen ingenieurs verblinden voor ontwikkelingen en mogelijkheden buiten hun blikveld (Nelson and Winter, 1982), waardoor 'core competencies' kunnen verworden tot 'core rigidities' (Leonard-Barton, 1992). Als actoren blijven geloven dat problemen binnen het bestaande regime kunnen worden opgelost, zullen ze langs bestaande innovatiepaden doorgaan en geen radicale alternatieven exploreren. *Normatieve* regels hebben stabiliserende effecten wanneer mensen hun gedragspatronen en lifestyles afstemmen op bestaande technologieën. Verder worden bestaande netwerken vaak gestabiliseerd door wederzijdse rolverwachtingen, identiteiten en 'sociaal kapitaal'. *Regulatieve* regels kunnen bestaande regimes stabiliseren door bindende contracten, standaarden of overheidssubsidies die bestaande systemen bevoorrechten (Walker, 2000). Vanwege deze stabiliserende mechanismen hebben bestaande sociotechnische regimes vaak een hoge mate van inertie en lock-in, iets dat Schumpeter ook al onderkende (zie boven). Binnen regimes is wel sprake van innovatie, maar dit heeft vaak een incrementeel karakter.

Vermindering van deze regime stabiliteit komt veelal door druk van buiten. Hier past het derde concept in het multi-level perspectief: het socio-technisch landschap. Dit is het macroniveau dat de brede context vormt voor het regime en de niches. Het gaat om ontwikkelingen en factoren die extern zijn aan het regime en de niches, maar daar wel invloed op hebben. De metafoor 'landschap' is gekozen om ook recht te doen aan materiële aspecten van de maatschappij, die invloed hebben op toekomstige ontwikkelingen (Rip and Kemp, 1998). Voorbeelden van dergelijke materiële aspecten zijn snelwegen, hoogspanningsnetten, ruimtelijke ordening, stedenbouw. Juist vanwege hun materiële verankering vormen deze aspecten een tamelijk stabiele context. Andere mogelijke aspecten van het landschap zijn cultuur, milieu, levensstijl, samenlevingsvormen, brede politieke coalities, macro-economische context, geopolitieke machtsverdeling.

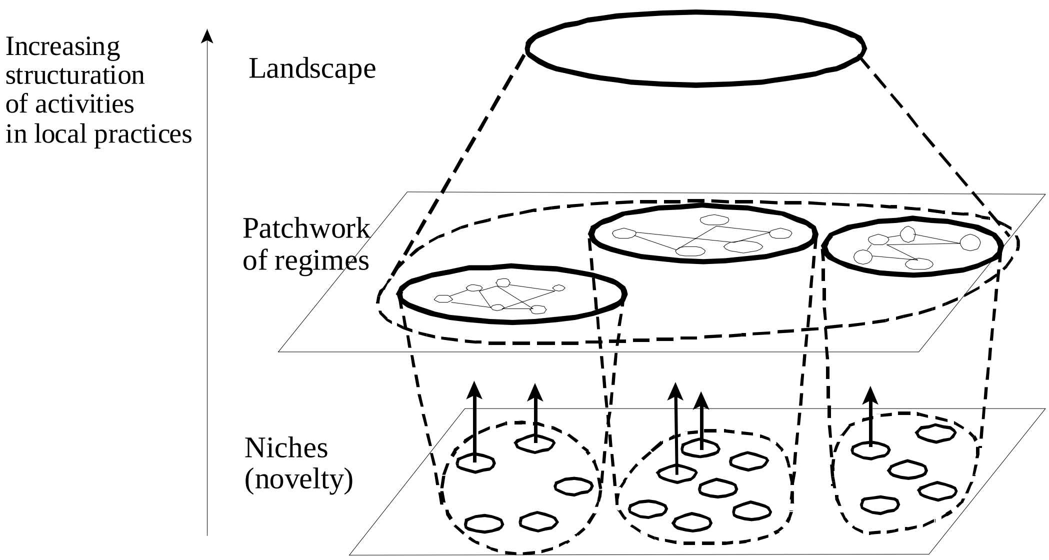
Een ander voordeel van de term 'landschap' is dat deze goed aansluit bij de term 'technologische trajecten'. Die trajecten kunnen makkelijk worden begrepen als paden door een landschap. Het landschap vormt als het ware de *gradiënten* die bepaalde technische paden makkelijker of moeilijker maakt (Figuur 1.4). Aan het eind van de 19^{e} eeuw, bijvoorbeeld, was er een cultuur van technisch optimisme en technische uitdaging. In deze cultuur waren de 'mankementen' van de benzineauto van 1890 juist aantrekkelijk. Rijke en technisch ingestelde avonturiers vonden de explosiemotor die met hand moest worden aangezwengeld, die soms ontplofte en die regelmatig onderweg gerepareerd moest worden, juist een spannend artefact. Het was een 'avonturenmachine' die goed aansloot bij de heersende cultuur (Mom, 1997). Die heersende cultuur *veroorzaakte* niet dat de benzineauto het won van de veel eenvoudiger te bedienen elektrische auto, maar vormde wel een gradiënt die invloed had op de concurrentie tussen benzineauto en elektrische auto.



Figuur 1.4: Topografie van sociotechnische evolutie (Sahal, 1985: 79)

Meestal gaat het bij het landschapsniveau om relatief langzaam verlopende trends en ontwikkelingen (de 'longue durée'). Soms echter doen zich plotselinge en onverwachte gebeurtenissen voor op landschapsniveau, die grote invloed hebben op niches en regimes, bijvoorbeeld oorlogen, grote ongelukken (bijvoorbeeld Tsjernobyl) of een olieschok doordat de OPEC de kraan dichtdraait.

De onderlinge relaties tussen de drie niveaus kan worden gezien als een geneste hiërarchie (Figuur 1.5).

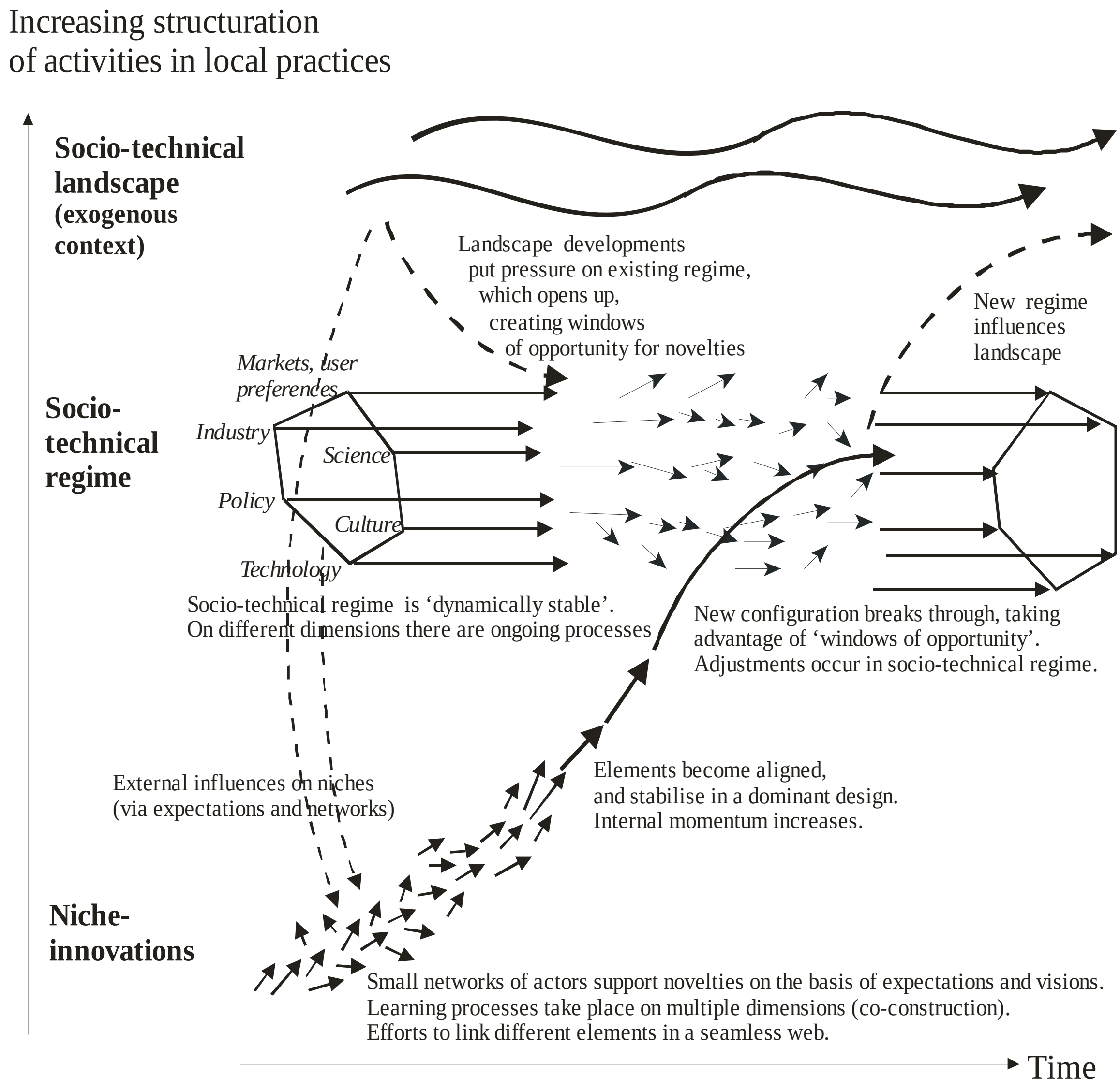


Figuur 1.5: Multi-level perspectief als geneste hiërarchie (Geels, 2002: 1261)

Het regimeniveau duidt op het gevestigde sociotechnische systeem bedoeld om een bepaalde maatschappelijke functie te vervullen. De functie 'personentransport' wordt bijvoorbeeld (voor het grootste deel) ingevuld middels het regime rond de auto met interne verbrandingsmotor. Dit regime heeft niet alleen betrekking op het artefact, maar ook op regelgeving (bv. emissies, belastingen, veiligheid), gebruikersgedrag en –voorkeuren, infrastructuur etc. Het landschap vormt de brede context voor het regime, of eigenlijk voor meerdere regimes. Sommige ontwikkelingen op landschapsniveau stabiliseren bestaande regimes, andere ontwikkelingen zorgen voor een druk. De niches vormen het niveau waar alternatieve innovaties ontwikkeld worden. Deze niches creëren een druk op het regime *van onderaf*. De niches proberen door te breken, maar dat is moeilijk zolang het bestaande regime stabiel is.

Het verloop van *hele* transities kan worden begrepen door de dynamiek tussen niveaus verder te conceptualiseren. Radicale innovaties ontstaan in afgeschermde niches. Ondanks de afscherming worden de sociale processen in de niches (leerprocessen, stabiliseren van strategieën, netwerkbouw) wel beïnvloed door ontwikkelingen op regime- en landschapsniveau. Strategieën en verwachtingen *in* een niche zullen bijvoorbeeld versterkt worden als de overheid strikte wetgeving afkondigt op regimeniveau. De vroege niche-innovaties nog geen bedreiging voor het regime, omdat de prijs/performance verhouding nog slecht is, en er veel ontwikkelingswerk nodig is. Bovendien kunnen niche-innovaties een mis-match hebben met infrastructuur, regelgeving, en gebruikerswensen in het regime.

Innovaties kunnen erg lang op het nicheniveau blijven vóór ze uitbreken. Bredere diffusie van niche-innovaties vindt plaats als drie processen elkaar versterken: 1) veranderingen op landschapsniveau die extra druk op het regime creëren (bijvoorbeeld klimaatverandering en toenemende normatieve bezorgdheid om dierenwelzijn), 2) afnemende stabiliteit van het regime; regime actoren zullen eerst proberen met incrementele innovaties aan de externe druk het hoofd te bieden; maar als dat niet goed lukt, zullen de percepties gaandeweg veranderen; het vertrouwen in het bestaande regime neemt af en de 'sense of urgency' voor verandering neemt toe; ook veranderingen in regelgeving of gebruikerswensen kunnen tot spanningen in het regime leiden. De afnemende stabiiliteit creert 'windows of opportunity' voor grotere verandering, 3) niche-innovaties kunnen alleen van deze windows gebruik maken als leerprocessen hebben geleid tot een dominant design met verbeterde prijs/performance eigenschappen; positieve leerprocessen, uitdijende netwerken en gedeelde visies kunnen niche-innovaties meer momentum geven, waardoor de kans op bredere diffusie toeneemt. Figuur 1.6 geeft deze koppelingsdynamiek schematisch weer.



Figuur 1.6: Multi-level perspectief op transities (aangepast van Geels, 2002: 1263)

Het nut van het multi-level perspectief voor het begrijpen van transitieprocessen is de laatste jaren bewezen met verschillende historische en contemporaine case studies: transitie van beerput naar rioolsysteem (Geels, 2006), transitie van zeilschip naar stoomschip (Geels, 2002), recente transitie in het elektriciteitssysteem (Verbong en Geels, 2007), recente transitie in Switzerse landbouwsysteem (Belz, 2004), opkomst van mee- en bij-stoken in elektriciteitsopwekking (Raven, 2004), de transitie naar rock 'n' roll (Geels, 2007), de transitie van pomp naar waterleiding en nieuwe hygiëne praktijken (Geels, 2005).

Verdere reflectie op deze case studies heeft tot theoretische verfijning van het MLP geleid. Geels en Schot (2007) onderkennen dat het MLP, zoals hierboven beschreven, eigenlijk één type transitiepad beschrijft, technologische substitutie, waarin een radicale innovatie ontstaat in niches en vervolgens breder doorbreekt en het bestaande systeem vervangt. Op basis van meer gedifferentieerde conceptualisering van interacties tussen de drie niveaus, onderscheiden Geels en Schot (2007) vier typen transitiepaden

1. Transformatie: In evolutionaire termen wordt dit pad gekarakteriseerd door veranderingen in de selectieomgeving, en ombuigingen (verandering van *richting*) in het bestaande traject doordat nu andere incrementele regime mutaties worden geselecteerd. Het is dus een geleidelijke transformatie door vele kleine stapjes. In sociologische termen wordt dit pad gekarakteriseerd door toenemende druk van outsiders (bv. maatschappelijke groepen, publieke opinie). In reactie daarop gaan regime actoren gaandeweg hun regels en routines aanpassen (bv. zoekheuristieken, guiding principles, belief systems), waardoor de richting van innovatieprocessen verandert. Het zijn dus de *bestaande* regime actoren die de transitie uiteindelijk in de praktijk brengen. Radicale niches spelen in dit transitiepad een minder grote rol. Er zijn wel experimenten, maar die vinden eerder plaats aan de randen van het regime (met welwillende voorlopers), dan buiten het regime.
2. Reconfiguratie: Ook in dit pad is vaak sprake van druk en protest van buitenstaanders, en zijn het regime actoren die de transitie uiteindelijk uitvoeren. Een belangrijk verschil is echter dat bepaalde component-innovaties, door outsiders (vaak suppliers) eerst zijn ontwikkeld in niches. Deze component-innovaties worden vervolgens geadopteerd door regime-actoren. Aanvankelijk worden deze componenten in het bestaande systeem ingepast (als add-on) of als componentvervanging. Door leerervaringen en nieuwe combinaties tussen oude en nieuwe componenten wordt echter gaandeweg de architectuur van het systeem veranderd. Niches spelen in dit pad dus wel een belangrijke rol, maar ze zijn meer symbiotisch met het bestaande regime dan dat ze er mee concurreren. Hoewel het transitiepad vrij geleidelijk is, kunnen er wel meer horten en stoten zijn, omdat de component-innovaties soms ook wat grotere effecten hebben.
3. Technologische substitutie: In dit pad is sprake van concurrentie tussen niche-innovatie en regime. Niches worden veelal ontwikkeld door outsiders of 'new entrants', die concurreren met de 'incumbents'. De uiteindelijke transitie gaat in dit pad vaak gepaard met de ondergang van bestaande actoren, wat Schumpeter 'waves of creative destruction' noemde. Het multi-level perspectief, zoals hierboven beschreven, is impliciet gebaseerd op dit pad. Ook veel van de bedrijfskunde en innovatieliteratuur richt zich op dit pad, vanwege de mogelijke kansen voor nieuwe bedrijven en gevaren voor bestaande bedrijven. Voorbeelden zijn te vinden in de literatuur over radical innovations, disruptive innovations (Bower and Christensen, 1995; Christensen, 1997), breakthroughs (Nayak and Ketteringham, 1986), en technological discontinuities (Anderson and Tushman, 1990).
4. De-alignment en re-alignment: Dit pad begint met snelle en grote landschapsdruk, waardoor het regime snel uit elkaar valt (de-alignment). Dit creëert een metaforisch vacuüm, wat stimulerend werkt voor het ontstaan van *vele* niche-innovaties.[4] Er is veel onzekerheid, omdat verschillende 'product champions' vele en soms conflicterende beloftes doen. De co-existentie van meerdere niches

1. [4] Een biologische analogie is het inslaan van Komeet, wat leidde tot de KT-extinctie waarin de dinosauriërs uitstierven. Deze overgang van het Krijt en het Tertiair werd ook gekenmerkt door een snelle evolutie en diversificatie van zoogdieren. Tijdens het dinosauriër 'regime' waren er ook al zoogdieren, maar die leefden als kleine knaagdierachtige wezens in kleine niches (vaak in holen onder de grond). De komeet-inslaag creëerde als het ware een vrije ruimte die de verdere evolutie van vele soorten zoogdieren stimuleerde.

creëert ook onzekerheid omdat niemand precies weet welke er gaat winnen. Deze onzekerheid vertraagt dan vaak grootschalige investeringen omdat actoren niet op het verkeerde paard willen wedden. Er is dus een aanzienlijke periode van co-existentie, leerprocessen, onzekerheid, en conflicterende claims en visies. Uiteindelijk wordt één van de niches dominant, en vormt dan de kern waaromheen een nieuw regime clustert (re-alignment).

Het multi-level perspectief blijkt dus behoorlijk flexibel, omdat verschillende interacties tussen de niveaus leiden tot andere transitiepaden. Voor het onderzoek naar transities in de glastuinbouw en varkenshouderij leidt dit dus tot een vervolgvraag: welk type transitiepad (of combinatie van deze ideaaltypen) werd er gevolgd?
Onze hypothese is dat deze transities een reconfiguratiepad volgden. In het conclusiehoofdstuk 6 komen we hierop terug.

1.4. Aanpak en methodologie

De onderzoeksstrategie is gebaseerd op kwalitatieve case studies. Dit is een uitstekende strategie voor 'hoe' en 'waarom' vragen, zoals in dit onderzoek (Yin, 1994). Bovendien is ons theoretisch perspectief co-evolutionair en multi-dimensioneel, met een focus op interacterende processen, context, en agency. Het onderzoek wordt dus gekarakteriseerd door 'process theory' in plaats van 'variance theory' (Abbott, 1992). 'Process theory' is gebaseerd op de aanname dat de wereld bestaat uit entiteiten (mensen, organisaties, technologieën) die participeren in gebeurtenissen: netwerkgrenzen, identiteiten en percepties kunnen dus in het proces veranderen. Voor dergelijke 'process theories' zijn case studies een geschikte onderzoeksmethode, omdat hiermee contextuele complexiteit kan worden meegenomen en omdat ze geschikt zijn voor 'process tracing' en 'pattern recognition' (George and Bennett, 2004).

Voor de historische case studies is dataverzameling gebaseerd op secundaire literatuur en archief-onderzoek, met name de nationale archieven, het archief van het Experimenteer Station Naalwijk, het bedrijfsarchief van Nieuw Honsel (een grote tuinder in het Westland), en de bedrijfsarchieven van voedselwerkende industrie (met name Hero). Voor de hedendaagse case studies komen gegevens uit semi-gestructureerde interviews met stakeholders, beleidsnota's, onderzoeksrapporten, en verslagen van demonstratieprojecten. Een aantal stakeholders heeft feedback gegeven op tussenresultaten en op de conceptversies van de geschreven artikelen.

1.5. Structuur van rapport

Met de wetenschappelijk directeur van de onderzoekslijn "Organisation of Innovation and Transition", Hans Mommaas, hebben we afgesproken[5] dat de eindrapportage van ons project zou bestaan uit een bundeling van 4 wetenschappelijke artikelen, een voor elke case studie, met een beredeneerde inleiding en een afrondende conclusieparagraaf met overstijgende lessen, evaluaties en conclusies. Op deze manier leveren we bijna twee keer zoveel output als was beloofd in de projectaanvraag (twee wetenschappelijke artikelen en een rapport).

[5] Email correspondentie in September 2007.

Hoofdstuk 2, 3, 4 en 5 bestaan dus uit Engelstalige wetenschappelijke artikelen zoals deze zijn ingediend bij internationale peer-reviewed tijdschriften. Hoofdstuk 2 en 3 zijn historische case studies over transities in de glastuinbouw en de varkenshouderij Hoofdstuk 4 en 5 zijn contemporaine case studies over radicale innovatietrajecten in beide sectoren. De titels, auteurs en tijdschriften voor de vier artikelen zijn:

2. Berkers, E. and Geels, F.W., 2008, 'Transitions and system innovation through stepwise reconfiguration: A techno-economic analysis of the transformation of Dutch greenhouse horticulture (1930-1980)
3. Geels, F.W., 2008, 'A multi-paradigm analysis of the transition from mixed farming to bio-industrial pork production (1930-1980)', *Research Policy* (submitted)
4. Boelie Elzen, Cees Leeuwis and Barbara van Mierlo, 2008, 'Anchorage of Innovations: Assessing Dutch efforts to use the greenhouse effect as an energy source' *Research Policy* (submitted)
5. Boelie Elzen, Frank W. Geels, Cees Leeuwis and Barbara van Mierlo, 2008, 'Normative contestation and transition pathways 'in the making': Animal welfare concerns and system innovation in pig husbandry' *Research Policy* (submitted)

Hoofdstuk 6 is geschreven door alle auteurs en betreft gezamenlijke reflecties op de vier case studies. Het hoofdstuk geeft algemene conclusies over patronen en mechanismen in transitie-dynamiek in de landbouw, met name de twee bestudeerde sectoren (glastuinbouw en varkenshouderij).

2. Transitions and system innovation through stepwise reconfiguration:
A techno-economic analysis of the transformation of Dutch greenhouse horticulture (1930-1980)

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Wordcount: 10.547

Abstract
Transitions and system changes are usually thought to come about through breakthroughs of technological discontinuities. This article proposes gradual, stepwise reconfiguration as additional transition pathway. In this pathway, innovations are adopted in the existing system and gradually reconfigure the basic architecture. New combinations of 'old' and 'new' elements thus gradually change the system in a stepwise fashion. Incumbent actors survive these transitions through learning, acquisition of new competencies and interactions with suppliers of knowledge and innovations. To analyze these knowledge flows, the paper extends the techno-economic network approach with institutional theory. The reconfiguration perspective is applied to and illustrated with an empirical case study: the transformation of Dutch greenhouse horticulture. The empirical study makes an 'outside-in' analysis that captures the whole transition and an 'inside-out' analysis that addresses knowledge flows in techno-economic networks. The former analysis identifies two specific patterns in the transition: 'straightjacket dynamics' and 'innovation cascades'.

Keywords: transition, system innovation, reconfiguration, knowledge flows, techno-economic networks, greenhouse horticulture

1. Introduction

This article contributes to the ongoing debate about technological transitions and system innovations, which has progressed under different headings, e.g. regime shifts (Van de Poel, 2003), technological revolutions (Perez, 2002), technological transitions (Geels, 2002) and system innovation (Elzen *et al*., 2004). These processes refer to shifts at the third level in Freeman and Perez's (1988) innovation typology: a) incremental innovation, b) radical innovation and technological discontinuities, c) changes in technology system, d) changes in techno-economic paradigm. So, the general topic is shifts from one system to another.

Much of the innovation studies literature assumes that transitions are driven by disruptive innovations (Christensen, 1997), breakthroughs (Nayak and Ketteringham, 1986), technological discontinuities (Anderson and Tushman, 1990), or pervasive technologies that lead to 'waves of creative destruction' and the downfall of established firms (Schumpeter, 1942).

This article shows that transitions can also follow another pathway: stepwise reconfiguration. Reconfiguration processes deviate from breakthrough transitions in three aspects: 1) the process is not driven by *one* major, radical innovation, but by *multiple* innovations, 2) these innovations do not compete with the existing system, but are incorporated as add-ons or component replacements; transitions then do not consist of fights between 'old' and 'new' technologies, but are more gradual processes in which new combinations of 'old' and 'new' gradually change the system's architecture in a stepwise fashion, 3) incumbent actors are not swept away by new entrants (as in 'waves of creative destruction'), but survive the process; incumbent actors enact the reconfiguration of the system architecture; the *development* of the innovations, however, often is done by other (outside) actors. Hence, the transfer of knowledge and innovations to incumbent actors is an important aspect of reconfiguration transitions.

Section 2 further elaborates this reconfiguration path in technological transitions, linking these three characteristics to relevant literatures. To illustrate its relevance, the reconfiguration perspective is applied to a case study: the transformation of Dutch greenhouse horticulture (1930-1980), which made the Netherlands into a world leader in tomatoes and flowers. Figure 1 indicates the rapid increase, especially after World War II, in tomato production and export.

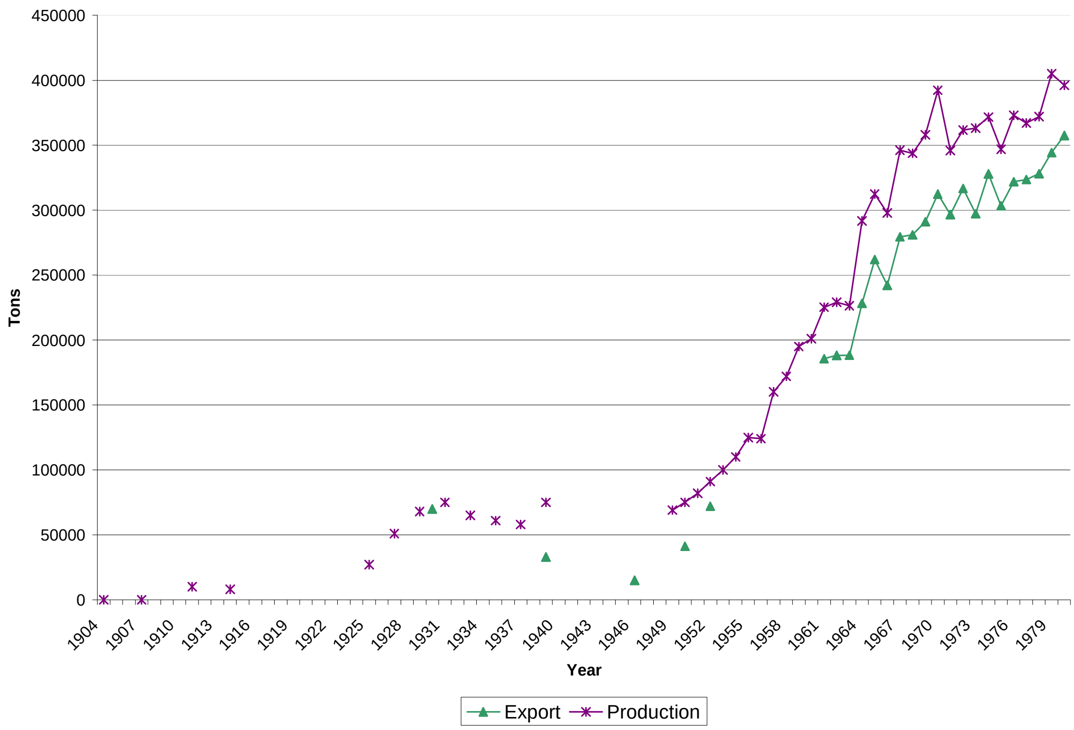

Figure 1: Dutch tomato production and export, 1900-1980 (composed from data in De Graaf, 1995; Gijsberts , 1964 and statistics from the Food and Agriculture Organization,www.fao.org; accessed on 3-2-2008)

This economic success is remarkable, because temperature, sunlight conditions and length of growing seasons in the Netherlands are not optimal for these crops. The cause of this success is the rapid transition in greenhouse horticulture in the postwar decades. This transition was not only about new technologies, but also about substantial changes in social networks, and regime rules (practices, guiding principles) (Geels, 2004). Important *technical* changes were (component) innovations in artificial heat, light, watering, disease control, CO_2 concentrations and crop varieties. The adoption of these elements led to a shift from 'Westland greenhouse' designs, with removable glass plates, to closed and insulated ‘Venlo greenhouse’ designs. With regard to *social networks,* the ties between farmers, universities, technology suppliers, and experimental stations became much stronger and more differentiated during the transition. With regard to *rules and practices*, horticulture changed from craft-based farming dependent on natural conditions (sun, rain) into a vegetable factory, with farmers working as production manager and machine operators. As greenhouse horticulture transformed towards year-round mass production of several products, it decoupled from the seasonal rhythms that characterized open air horticulture. Major changes thus occurred on all three dimensions.

The case study is analyzed in two sections, providing subsequently an 'outside'-in' analysis and an 'inside-out' analysis. In this respect, we build on Poole and Van de Ven (1989) who argue that process theories should have two complementing components: global and local models:

> "The global (macro, long-run) model depicts the overall course of development of an innovation and its influences, while the local (micro, short-run) model depicts the immediate action processes that create short-run developmental patterns. (...) A global model takes as its unit of analysis the overall trajectories, paths, phases, or stages in the development of an innovation, whereas a local model focuses on the micro ideas, decisions, actions or events of particular developmental episodes" (p. 643).

Section 3 provides an 'outside-in' (global) analysis of the overall transition, addressing the following research questions: How did the transition in greenhouse horticulture come about? Did the transition follow a reconfiguration pathway? Can we distinguish particular patterns in this pathway? Section 4 makes a complementary 'inside-out' (local) analysis of the actors and their interactions, focusing on knowledge flows between the agricultural university, which did formal research and development, and horticultural farmers (often family firms). The article ends with conclusions in section 5.

2. Reconfiguration dynamics in transitions

1) Multiple component innovations in distributed systems

The difference between breakthrough and reconfiguration transitions correlates to some extent with the architecture of socio-technical systems. Breakthrough dynamics are more likely in systems that are organized around a 'core' technology. Examples are car the in the road transport system, aircraft in aviation systems, television and video in visual home entertainment, the telephone in telecommunications, recently supplemented by Internet and email. While these technologies need complementary innovations to fulfil functionalities, the literature distinguishes between ‘core’ and ‘peripheral’ technologies (Henderson and Clark, 1990). Transitions in these kinds of systems usually come about through breakthrough and substitution dynamics: a technological discontinuity or radical innovation emerges and subsequently replaces the core technology.

Reconfiguration dynamics are more likely in 'distributed systems' or 'configurational technologies' (Fleck, 1994), which function through the interplay of *multiple* technologies that are equally important. Retailing systems, for instance, require multiple technologies for transport, packaging, storing, cooling, scanning and payment. Hospitals and medical systems also involve a wide range of technologies for different activities (e.g. diagnosis, operation, treatment, care). Greenhouse horticulture is also a distributed system, involving technologies for heating, lighting, fertilizing, watering, irrigation and drainage, sheltering and protection, disease treatment. In these distributed systems there is no ‘core’ technology that can be substituted by a single breakthrough innovation. Hence, transitions in distributed systems come about through *multiple* (component) innovations, which may leave the system's architecture intact (modular innovation) or alter it (architectural or radical innovation).

2) Component innovations and system reconfiguration

Innovation in complex technical products or systems can be directed at components, architectures or a combination of both (Henderson and Clark, 1990). *Modular innovation* means that components are replaced without affecting other components or the system architecture. *Architectural innovation* means that the components stay the same, but the linkages between them change. *Radical innovation* involves changes in both components and architecture (Table 1).

	Components reinforced	**Components overturned**
Architecture unchanged (linkages between components)	Incremental innovation	Modular innovation
Architecture changed	Architectural innovation	Radical innovation

Table 1: A framework of innovations (Henderson and Clark, 1990: 12)

Modular innovation is possible when linkages between system components are characterized by *loose coupling* (Simon, 1973). Loose coupling means that components operate dynamically in independence of the detail of other components; they are only connected through functional inputs and outputs. In technical systems, loose coupling means that components are organized as independent modules. This permits modular innovation and improvements or replacements within one component without requiring synchronous changes in other components that make up the system. Modular innovation thus enables distribution of labour, specialisation, and flexible innovation (Sanchez and Mahoney, 1996; Baldwin and Clark, 1997).

These innovation categories do not always remain neatly separated. Sometimes change begins as 'modular innovation' and subsequently triggers adjustments in other components, leading to 'architectural' or 'radical innovation'. The jet engine, for example, began as a modular innovation (replacing the piston engine), but subsequently triggered innovations in other parts of the airplane (e.g. swept-back wings, size) and aviation system (longer runways, adjustments in air traffic control systems) (Geels, 2006). The more general point is that system changes can occur through sequences of stepwise component innovations, which begin as modular innovations but end up as radical (system) innovations. These modular innovations may replace existing components or add new modules to the system (symbiotic add-on). Broader system change occurs when old and new modules lead to new combinations that change the system's architecture.

The distinction between loose and strong linkages also has implications for degrees of inertia in system change. Systems that are organized around core technologies tend to have strong linkages between components. which creates inertia and resistance to change. In distributed systems, where components are functionally aligned through loose coupling, this kind of inertia is less prominent. Hence, there tends to be less resistance to the adoption of innovations in the system, especially when they offer improved performance.

3) Incumbent firms and knowledge flows

Reconfiguration processes are enacted by incumbent actors, who adopt and incorporate (component) innovations in existing systems. Other actors, such as universities or technology suppliers, often develop these innovations, often in interaction with incumbents. Interactions and knowledge flows are therefore important in reconfiguration processes. To conceptualize these dynamics, we add to the notion of 'techno-economic network' which is a “coordinated set of heterogeneous actors, e.g. public laboratories, technical research centres, industrial firms, financial organisations, users, and public authorities, which participate collectively in the development and diffusion of innovations” (Callon *et al*., 1992: 220). In the original approach, science, technology and market form the three main 'poles' in a techno-economic network, linked by two transfer networks (Figure 2). In Callon's actor-network theory, networks not only consist of actors, but also of intermediaries which circulate between the poles and give the networks material content. These intermediaries can be written documents (scientific articles, reports, patents, etc.), people and their skills, money (e.g. contracts, loans, purchase), and technical objects (e.g. prototypes, machines, products).

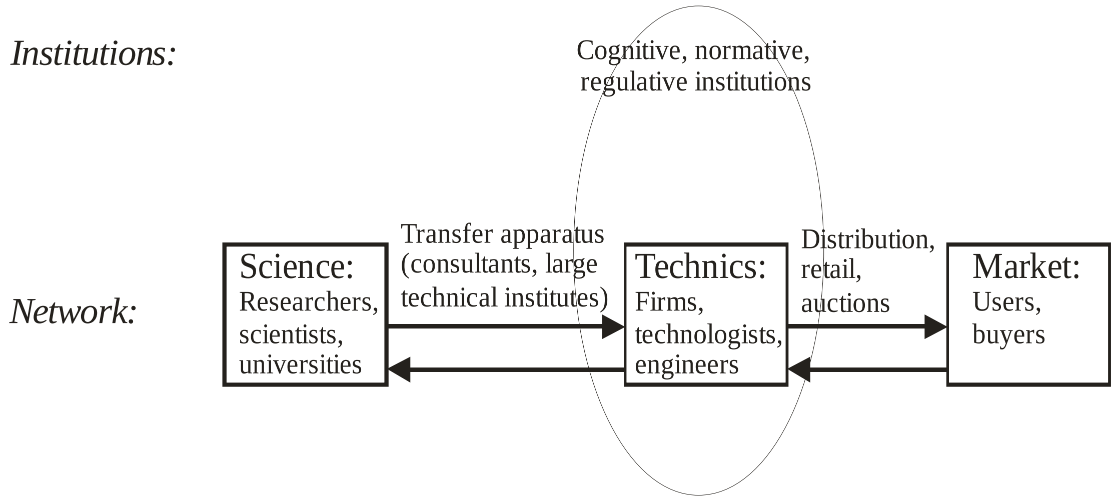

Figure 2: Techno-economic network and institutions (adapted from Callon et al., 1992: 222)

In Figure 2, we have added 'institutions' to the technical pole (greenhouse horticulture in the case study below). We acknowledge that this addition is at odds with the foundational ontology of actor-network theory, which conceptualizes the world as 'flat' (or folded), denies the usefulness of 'vertical' conceptualisations of institutional structures, and understands coordination as arising only from circulation and ongoing network interactions.[6] Nevertheless, we have added 'institutions' to the TEN-approach, because they also contribute to coordination, in our view. Building on institutional theory (Scott, 1995), we further distinguish regulative, cognitive, and normative institutions. Examples of regulative institutions are standards, laws, regulations. Examples of cognitive institutions are belief systems, problem agenda's, guiding principles, search heuristics. Examples of normative institutions are role relationships, behavioural norms, social attitudes. These institutions positively or negatively influence interactions and knowledge flows within techno-economic networks. Section 4 uses this expanded techno-economic network perspective to make an analysis of the knowledge flows in Dutch greenhouse horticulture during the post-war transition.

3. The reconfiguration of Dutch greenhouse horticulture (1930-1980)

Figure 3 provides an overview of the expansion of Dutch greenhouse farming in the 20th century. Vegetables (especially tomatoes) and fruits (especially grapes) were the main crops until 1970. In the 1950s and 1960s, lettuce, eggplant, and peppers were also grown in improved greenhouses. In the 1970s, a relative shift occurred towards flowers and pot plants. In terms of crops, the case study focuses on tomatoes, which were the dominant crop for most of the period. Most of the tomatoes were exported (see Figure 1), especially to Germany and Britain, making Dutch horticulture sensitive to changes in international demand.

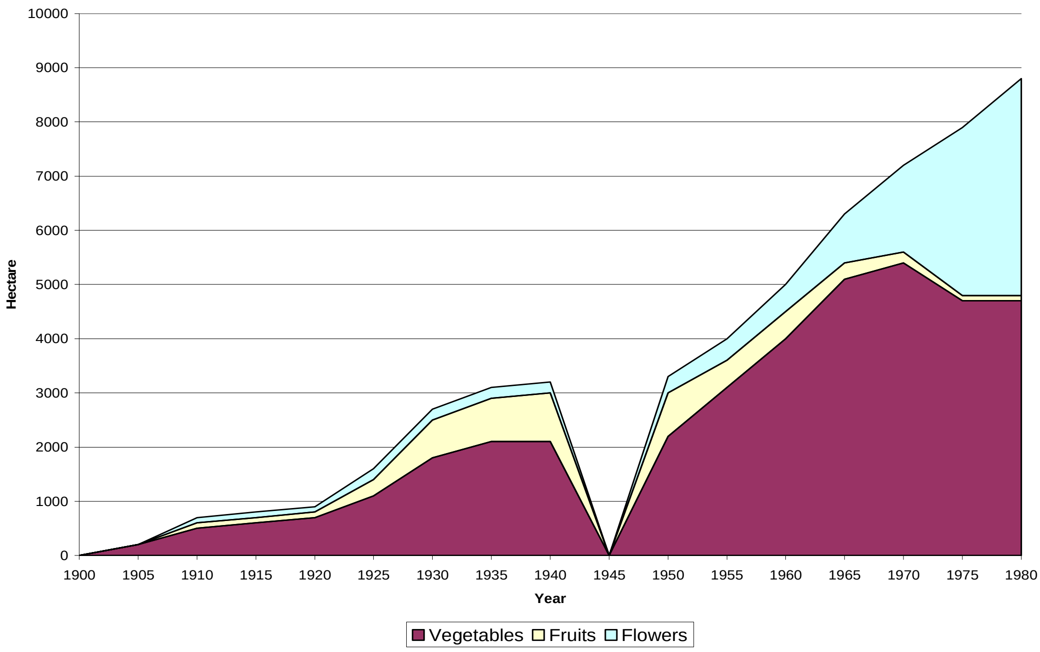

Figure 3: Expansion of greenhouse horticulture per crop category, 1900-1980 (Plantenberg, 1987)

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[6] "So you are freed from this image of a multilevel society. You don't need several layers, different layers. You don't need infrastructure and superstructure and embeddedness. You only need places that are connected and the possibility of actors and information to circulate from one place to another one." (Callon, 2002: 293)

The 'outside-in' analysis of transition dynamics has a geographical focus on the largest Dutch greenhouse area called ‘Westland’, situated between Rotterdam, Delft, The Hague and the North Sea border. The Westland acquired the nickname ‘city of glass' before the Second World War, and became *the* symbol for the horticultural transition in the post-war period.

The empirical data come from secondary sources and from primary research in the National Archives of the Department of Agriculture (Agricultural Directorate, National Agency for Horticultural Economics), the archives of the Municipality of Naaldwijk and The Westland Museum, company archives of the tomato-pioneering horticultural company 'New Honsel' (deposited at the Municipal Archives of The Hague), and company archives of two food-processing companies, Hero (deposited at the Brabants Historical Information Centre in Den Bosch) and De Betuwe (deposited at the Regional Archives in Tiel).

The analysis focuses on the existing horticultural system (socio-economic developments, market dynamics for different crops, technical bottlenecks and functional problems), the development of new component innovations (techno-scientific research, experimental projects), and diffusion and uptake in the system (knowledge flows between universities and farmers, adoption and investment decisions, techno-economic considerations, government regulations). These aspects are analyzed for three periods: stabilisation of the 'Westland greenhouse' system (1930-1945), tinkering and reconfiguring the system (1945-1965), expansion and take-off of the new system (1965-1980).

3.1. Stabilisation of the 'Westland greenhouse' system (1930-1945)

The ‘Westland greenhouse’ system

The ‘Westland greenhouse’ originated from Guernsey, the British Canal Island with important horticultural commerce (Harvey *et al*., 2002), and appeared in the Netherlands around 1910. While the existing grape greenhouses were designed for mono-crops, the 'Westland Greenhouse' was more versatile and suited for various crops (Figure 4). The 'Westland greenhouse' diffused rapidly between 1910 and 1930, especially because of expanding tomato business (Van den Muijzenberg, 1980).

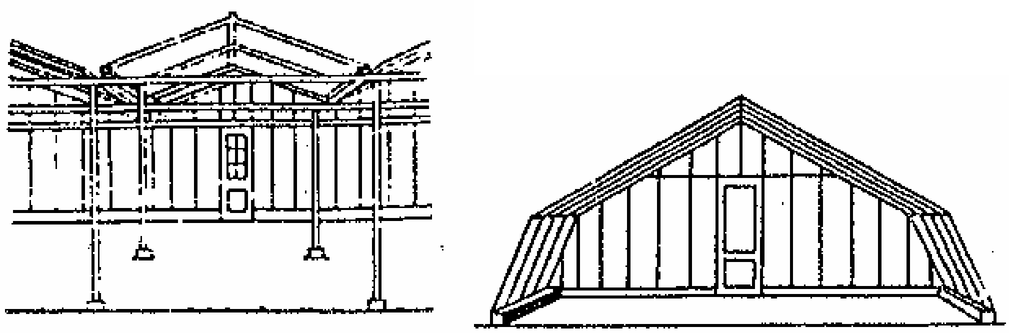

Figure 4: 'Westland greenhouse' and 'grape greenhouse' designs (Vijverberg, 1996)

On technical dimensions, the 'Westland Greenhouse' design was an improvement over existing closed glasshouse designs. These closed designs experienced problems of soil dehydration and accumulating salt concentrations, as explained by an horticultural manual in 1933:

> "For soil that is situated high above groundwater, the upper layer dehydrates so much, that it cannot be moisturized by sprinkling only. After repeated rainfalls only – usually occurring in November and December – the original moisture can be restored" (quoted in Vijverberg, 1996: 57).

In 'Westland greenhouses' the top glass plates could be removed, especially during winter months, allowing rains to flush the soil and improve fertility. A disadvantage was that the removable glass plates made the 'Westland greenhouse' leaky and draughty, increasing the risk of plant diseases (Vijverberg, 1996).

Farmers initially used greenhouse farming as an ‘add-on’ to their open-air practice to earn additional incomes. Early greenhouse farming was close to open-air horticulture, in the sense of dependence on natural inputs and influences, e.g. sunlight for growth and heat, manure for fertilizing, and rainwater for periodic flushing. Daily watering, however, was done with hoses or buckets, which was labour-intensive work.

The social network was dominated by private actors, with the government only indirectly involved through funding of actors in the so-called ERE-triptych (education, research, extension). Government involvement increased strongly during the economic crisis of the 1930s. This crisis deeply affected horticulture, as export volumes of vegetables more than halved between 1929 and 1935 (Bieleman, 1992). The price for tomatoes plummeted from 25.58 guilders in 1930 to 9.54 guilders 1935 (National Archives, no. 232). Enhanced government involvement helped farmers survive the crisis by providing interest-free loans and direct income support.[7] To combat over-production and decreasing prices, the government set production restrictions. The scale of government support was massive. Between 1933 and 1936, total expenditures of the Agriculture Crisis Fund were 200 million guilders per year (Bieleman, 1992). Horticulture in the Westland received about 23 million guilders as direct government support (Kemmers, 1964).

The Department of Agriculture also stimulated new product development and the creation of new markets. Wageningen Agricultural University, for instance, was encouraged to collaborate with food-processing companies Hero and De Betuwe to develop new soft-drinks from tomatoes, grapes, and apples. Despite initial hesitations, these soft-drinks became a big success in the second half of the 1930s (Zwaal, 1993; Hero company archives, no. 35). The Ministry of Social Services also approached Hero to process tomatoes into tomato purée, which it could use for tomato soup in the crisis' soup kitchens (Hero company archives, no. 6).

Agricultural markets gradually recovered during the late 1930s. The tomato price gradually increased from 10.69 guilders in 1936 to 15.69 in 1937, 22.06 in 1938, and 25.68 in 1939 (National Archives, no. 232). But the financial position of many farmers was still fragile. Hence, innovations that had been developed in previous years (see below), were limitedly adopted. Only incremental changes to the 'Westland greenhouse' were made: decreasing size of construction elements, increasing size of glass plates, placing top glass plates in more tilted positions towards the sun. These changes aimed to enhance natural light penetration in greenhouses, because laboratory research had shown that more light contributed substantially to growth rates and yields (Van den Muijzenberg, 1980; Boersma, 2004). Also the influence of different glass variations on sunlight penetration was investigated.

Techno-scientific development of new component innovations

[7] If auction prices fell below certain levels, the government paid farmers the difference.

More radical (component) innovations were developed in laboratories and test stations. Artificial light and irradiation of plants, for instance, was investigated by Philips, which started a research project in 1928 together with Wageningen Agricultural University, the electro-technical industry, electricity companies and standardization committees (Boersma, 2004). For farmers, this innovation promised to lengthen the daily light period which might stimulate plant growth. For other project partners, the commercial promise was that horticulture might become a possible market niche for special electric lights. The Horticultural Experimental Station in Naaldwijk provided experimental space for the testing of Osram-lamps, Vitalux-lamps and Neon tubes in real-life greenhouses (Barendse, 1949; Boersma, 2004). These tests showed that heat production from the lamps was a significant problem, requiring precision control of the light-temperature ratio. Artificial lighting did not diffuse widely in the 1930s, partly because of these technical and operational problems and partly because of bad economic conditions. In the late 1930s Philips therefore terminated the research project (Stender, 1964; Boersma, 2004).

Artificial heating was also investigated. In 1910, the Horticultural Experimental station for the Westland tested coal and cokes burners that heated water, which was disseminated through greenhouses with pipes and radiators (Stender, 1964). On the one hand, higher temperatures stimulated growth rates and crop yields, and enabled extension of the growing season in time, allowing more yields per year. On the other hand, artificial heating led to additional purchase and fuel costs, and additional labour costs, because coal burners required skilled operators and regular maintenance. Careless heating could also lead to temperature fluctuations, which enhanced disease receptiveness. Furthermore, much heat was lost through the cracks around the removable plates of 'Westland greenhouses'. Because of these economic and operational difficulties, artificial heating was limitedly used in the 1920s and 1930s. Only innovative and large horticulturalists with sufficient personnel and skills (such as the 'New Honsel' firm, a Dutch pioneer in greenhouse tomatoes), experimented with heated glasshouses (New Honsel Company Archives, no. 1).

Research also focused on soil conditions and fertility, in particular artificial fertilizers, based on chemical combinations of phosphates or sulphates. In the 1930s, the Soil Laboratory of the Westland Experimental Station (in Naaldwijk) tested fertilizer compositions for different crops, interacting about the findings with Wageningen Agricultural University and chemical factories such as Delftsche Gist- en Spiritusfabriek (Barendse, 1949). Soil researchers also addressed the problem of high salinity that turned parts of the greenhouse soil into 'dead' spots. The removable glass plates of the 'Westland greenhouse' formed one response to this problem (providing periodic flushing in rainy periods). But this design was leaky and windy, which caused diseases and led to heat loss. Hence, researchers began investigating other solutions such as above-ground sprinkling systems and underground drainage technologies (Vijverberg, 1996).

3.2. Incorporation of new elements and tinkering with the system (1945-1965)

War damage to greenhouse farming was substantial, with 1.786.300 m^2 of horticultural glass being broken or damaged. Greenhouse reconstruction to the level of 1939 would require 900.000 m^2 glass plates, 568.000 m^2 small glass plates, 1.670.000 window frames, 175.000 meter of heating pipes, 30.000 meter of narrow-gauge railway, 400 central heating boilers, and 500 motor pumps (Van Doesburg *et al.*, 1999; Dekker, 1964). Investments in the immediate post-war years were allocated to these basic repairs, not to major innovations. This was also due to uncertain economic prospects in the late 1940s.

In the 1950s and early 1960s, many new technologies such as artificial heating, artificial lighting, water sprinkling and irrigation systems, and new crop varieties entered the greenhouse. This required a lot of tinkering and tailoring of different elements to each other. These learning processes gradually transformed not only the technical characteristics of greenhouses but also the farming practice, which changed from craft based farming to technical entrepreneurship.

These changes in greenhouse farming were stimulated by: a) ‘pull factors’ such as enhanced market demand, market liberalization and export, b) changing economic incentives (rising labour costs) and c) changing government policies. We irst discuss these contextual changes and then turn to greenhouse farming.

a) In the early post-war years, bilateral trade treaties regulated horticultural exports. The trade in greenhouse vegetables and fruits was limited, because they were seen as luxury products. In 1949, a trade and clearings treaty with West-Germany created new export opportunities for vegetables and fruits. In 1956, the European Economic Community was formed. And in 1958, the Common Agricultural Policy created an open European market for agricultural products.

While the European market liberalization created favourable conditions, the export of greenhouse products was especially stimulated by strong international demand related to a general improvement of economic conditions in the 1950s. The strong growth in West-German national income (the 'German miracle') translated into consumer demand for horticultural products. Between 1950 and 1960, German tomato imports more than quadrupled from 53.000 tons to 222.572 tons. In this period, Dutch horticulturalists boosted their competitiveness and market share. In 1950, 40% of the German tomato imports came from the Netherlands and 51% from Italy. In 1960, 55% came from the Netherlands and 17% from Italy. For Britain, the second Dutch export market for tomatoes, exports increased from 15.000 to 37.000 tons between 1950 and 1960, with Dutch farmers increasing their market share from 8% to 16% (Gijsberts, 1964).

Also domestic demand for agricultural products grew, as Dutch national income increased almost 200% between 1950 and 1970. Also consumption preferences changed as cheap, nutritious but heavy vegetables, such as cabbages, were gradually replaced by lighter, more refined, and more expensive vegetables, often grown in greenhouses (Gijsberts, 1964). Tomatoes increasingly appeared on the menu, in salads or accompanying meat, and were also increasingly used by food industries in processed foods such as spaghetti sauces, tomato soups and drinks (tomato juice). Table 2 demonstrates the rapid growth in the Dutch export and domestic consumption of tomatoes during the 1950s.

	Export (tons)				**Interior consumption (tons)**		
	Tomatoes	**Grapes**	**Lettuce**		**Tomatoes**	**Grapes**	**Lettuce**
1939	32970	6600	18650		4670	9860	19610
1946	14970	6010	10050		18920	8310	33090
1950	41220	7610	12770		18700	7410	27540
1951/53	71600	6200	17500		18100	6800	28500
1960/62	179500	2000	43900		29600	8700	35200

Table 2: Markets for main Westland horticultural products, 1939-1960 (Gijsberts, 1964)

The exports of grapes declined in the late 1950s both in volume (Table 2) and value (Table 3). This was due to increased competition from Southern European countries, especially after 1958 when the Common Agricultural Policy created an open European market. Dutch farmers could not compete, because rationalization and cost reduction in grape growing was more difficult than for other vegetables (Dekker, 1964). As grapes marginalized, tomatoes became the symbol of a modern and innovative Dutch horticultural sector. Lettuce and other fruits from (heated) greenhouses also benefited from the new export opportunities. By 1965, 75% of horticultural products on Dutch auctions went to export markets (Gijsberts, 1964).

Product	1939	1949	1951	1955	1962
Grapes	33	26	18	14	6
Tomatoes	22	29	37	44	51
Lettuce	7	4	8	9	21
Early potatoes	4	2	2	1	0.5
Other fruits	7	8	8	5	3
Other vegetables	27	31	27	27	18.5

Table 3: Trade at Westland auctions in terms of value percentage per product, 1939-1962 (Dekker, 1964: 31).

b) While rising wages stimulated consumer demand, they also increased labour costs, which formed an incentive for the shift from labour to capital, which generally occurred in post-war agriculture (Bieleman, 1992). To increase labour productivity, innovative farmers invested in machines and technologies. The trend towards mechanization enabled farmers to work larger plots of land and increase their production. Greenhouse farmers, which faced strong competition from Southern European countries in export markets, also invested in new technologies to stimulate their productivity and competitiveness.

While investments always have some uncertainty, the shift to mechanization and rationalization was doubly uncertain, because it required a new mentality of entrepreneurship (Defares, 1986). Farmers were used to save first, and then invest. But now they had to borrow large sums of money from banks, make investment plans, learn economic planning and book keeping. The government, agricultural schools and extension services played important roles in this learning process (see below).

c) The regulation of markets and production, which originated from the 1930s crisis and the war, were gradually abolished. Guaranteed minimum prices for vegetables and fruits, for instance, were stopped in 1948 (Bieleman, 1992). In 1949, the government relaxed the system of growing permits, providing space for horticultural expansion. Production licenses were particularly granted to farmer's sons. Because little land was available for arable or dairy farming, these farmer’s sons had to turn to intensive forms of agriculture, such as greenhouse horticulture.

In the 1950s, the national government developed a new vision of agricultural modernization that should secure four goals (Louwes, 1980): 1) food security: reliable and sufficient food supply ('no more hunger'), 2) cheap food supply: low food prices would allow low wages, which would stimulate industrialization, 3) reasonable incomes for farmers (guaranteed livelihood), 4) increased export, so that agriculture would improve the national balance of payments. To achieve these goals, the government favoured rationalization, mechanization, and scale increase.

One policy instrument was the expansion of the ERE-triptych, aimed at disseminating scientific practices and new technologies to farmers (Van den Brink, 1990). The number of employees at the Agricultural Extension Service tripled, from 500 in 1946 to 1420 in 1950 to 1580 in 1956 (Zuurbier, 1984). Extension experts gave presentations for farmers, visited study clubs, distributed reports, and organized excursions to model farms. While the information initially focused on new technological possibilities, economic and investment information gradually became more important. A similar change occurred in the expensing number of agricultural schools, which between 1950 and 1960 increasingly paid attention bookkeeping and agricultural entrepreneurship (Duffhues, 1996). The Horticultural vocational school in Naaldwijk, for example, introduced courses in 'Horticultural economy', 'Commercial correspondence' and 'English'. By disseminating new practices regarding money and investing, agricultural schools and extension experts helped to transform farmers into entrepreneurs who borrowed money from banks if cost-benefit calculations of investment decisions were positive (Crijns, 1998).

The government also stimulated borrowing and investments with payback guarantees on the loans that banks provided. And in 1963, the Development and Buy Out Fund was introduced to provide subsidies to innovative farmers who want to mechanize and expand (Van den Brink, 1990). The fund also provided buy-out subsidies to small farmers who wanted to stop, thus facilitating take-overs and scale increases.

Modernization and mechanization were further promoted with regional improvement projects, which subsidized 50% of the costs of new technologies (Van den Brink, 1990). By reducing the risks of investment decisions, these projects hoped to stimulate early diffusion, learning processes and bandwagon (imitation) effects. The Westland horticultural area also benefited from some of these regional improvement projects.

In these changing economic and policy contexts, improved and new component innovations gradually entered the greenhouse system. Until 1950, tomatoes were mainly grown in unheated greenhouses during the summer-season. In the early 1950s, oil-fired heating systems became more popular. Oil stoves were cheaper than coal stoves, were easier to operate (turning the oil tap was easier than shovelling coal into furnaces), and required less maintenance. As international competition with Southern European farmers grew fiercer, oil heating further diffused. Artificial heating not only created higher temperatures, but also extended the growing season with several months (Van Soest, 1964). Together with artificial lighting it even created the new possibility of year-round crops.

The attitude of greenhouse farmers towards artificial heating was generally positive. Boilers and pipes became symbols of modern entrepreneurial horticultural farming (Vijverberg, 1996). More pipes and chimneys and larger areas of glass signified higher social standing. Oudshoorn (1957) reports an anecdote from 1954, when a horticulturist from Poeldijk, a city in the Westland, did not appear at his daughter's wedding, because his son in law was the son of a horticulturist with fewer pipes.

While artificial heating implied additional fuel costs, higher productivity during more months led to increased production and higher revenues. Operation of heating installations, and thus personnel costs, was further simplified by the introduction of automatic heat and temperature regulation devices, which also meant less temperature fluctuations than with coal burners. Heating technology suppliers and the Horticultural Experimental Station in Naaldwijk also worked on more efficient boilers and heat distribution systems, aimed at reducing fuel costs. The Experimental Station also provided technical and economic advice to horticulturists with regard to greenhouse heating. A 'fuel-economy' consultant provided dedicated heating courses for interested farmers (Stender, 1964). Between 1954 and 1964 the area of heated greenhouses in the Westland increased from 30% to 50% (Dekker, 1964).

The unexpected side-effect of increased artificial heating was air pollution in the form of soot and smog. Soot exhaust negatively affected greenhouse farming, because deposition on glass surfaces hindered natural light penetration. Soot deposits in residential neighbourhood also damaged the public image of greenhouse farming.

A positive side-effect of artificial heating was CO_2 fertilization. When research showed that higher CO_2 concentrations (0.1% instead of the normal 0.03%) stimulated plant growth, horticulturalists in the early 1960s rapidly adopted methods to increase CO_2 concentrations, e.g. burning additional propane gas or paraffin and releasing exhaust gases within the greenhouse (Stender, 1964).

The self-generated steam from artificial heating also made soil disinfection possible, combating soil-diseases and fungi. In 1960 this was facilitated by new synthetic materials which enabled horticulturists to released steam under large soil areas covered with heat-resistant plastic sheets.

Artificial lighting returned on the agenda in the late 1940s, when Philips restarted its agricultural research program into relations between artificial light and crop growth (Boersma, 2004). While some greenhouse farmers adopted fluorescent tubes in the mid-1950s, high costs and uncertainties about precise performance effects hindered wider diffusion. During the 1960s and 170s researchers from Philips and the Institute for Horticultural Engineering tried to improve performance improvement and reduce costs (National Archives, no. 15). But, it was not until the 1980s that artificial light became widespread for certain crops, especially flowers (Van Doesburg *et al.*, 1999). While artificial lighting remained difficult, horticulturalists did adopt more incremental innovations that enhanced the inflow of *natural* light, e.g. new glass qualities with better light distribution qualities and new greenhouse designs with wider glasshouses, more glass and less support beams (Van den Muijzenberg, 1980).

Artificial watering was an important labour-saving device. Because watering by hose or bucket was labour-intensive, horticulturalists adopted spray systems with electric pumps in the mid-1950s (Vijverberg, 1996). The addition of automation, via control panels and electric taps, further reduced labour demands and enabled the tailoring of water supply to particular crop needs (Van Doesburg *et al.*, 1999).

Artificial water systems also facilitated periodic soil flushing to prevent salt accumulation. The combination of flushing with the necessary underground drainage systems led to improved soil desalinization, which expanded the variety of crops that greenhouse farmers could grow. In the late 1950s, lettuce, a very salt-sensitive crop, could be produced all year round, making it the second most important greenhouse crop, after the tomato (Van Soest, 1964).

Greenhouse horticulture also benefited from biological innovations. Advances in breeding produced new tomato breeds that could grow under a variety of (seasonal) conditions. Pale varieties, such as the Victory, gradually replaced traditional races such as Ailsa Craig and Tuckwood. Improved breeding techniques also influenced other crops such as cucumbers, and produced lettuce varieties for different seasons (Van Soest, 1964).

Higher temperatures and extended growing seasons also led to new diseases. Mildew, a fungous infection of the leaves, often plagued greenhouse tomatoes. Other common diseases were *kurkwortel*, a soil-disease that affected the roots, and 'blossom end rot'. In response, scientists tried to graft tomato varieties onto resistant rootstocks and developed disease suppressing chemicals (Van Soest, 1964). More difficult to combat were the tomato mosaic virus and botrytis, which both occurred at high humidity. Because disease treatment was only moderately successful, the best remedy was prevention. Regular soil disinfection with steam was one option. Regular disease tests for soil and crops was another, which provided additional work for the Horticultural Experimental Station where the number of soil-tests increased from 15.000 in 1965 to 50.000 in 1975 (Van Soest, 1964).

The incorporation of different component innovations into the existing 'Westland greenhouse' created opportunities for more encompassing architectural innovations in greenhouse design. By the late 1950s, the limitations of the existing design were increasingly recognized. The 'Westland greenhouse' prevented innovations such as artificial heating, CO_2 fertilization, and ground steaming to reach their full potential, because leaks and cracks around the removable top plates led to heat loss and CO_2 dissipation. Hence, the 'Westland greenhouse' came to be seen as a straightjacket, a bottleneck for further modernization. The late 1950s therefore saw a shift to a new design: the 'Venlo greenhouse' with isolated, closed and fixed-glass rooftops (Stender, 1964). In the 1930s, this design had emerged in a smaller horticultural area in the South-East of the Netherlands, near the city of Venlo. Because Venlo was situated on hills, horticulturalists could adopt closed, fixed-glass rooftops without encountering the normal salt accumulation problems. Downhill underground drainage streams automatically washed salt from the greenhouse soil (Vijverberg, 1996). In the late 1950s, the 'Venlo greenhouse' that could be transferred to the Westland, because water sprinkling, flushing and drainage systems had solved the salt accumulation problem. These technical innovations thus made the removable glass plates of the 'Westland greenhouse' redundant.

The component innovations and new greenhouse design not only changed the technical aspects, but also affected farming practices. Artificial heat, light, fertilizer, disease control and watering systems made greenhouse horticulture less dependent on natural fluctuations. Greenhouse horticulture gradually transformed into a year-round vegetable factory, with farmers working as production manager and machine operators. The expanding numbers of chimneys reinforced associations with industrial centres. The tomato, which was the trailblazer of greenhouse farming, changed from a summer treat to a year-round product. To rationalize production, farmers also began to focus on single crops leading to more specialization. In a 1964 memorial book, one of the authors complained about the loss of variety, which made work more monotonous. "In 1940, a single company of 2 to 3 hectares often produced blue and white grapes, peaches, plums, endive, tomatoes, sprouts, cauliflower, onions, berries, and maybe had some pigs, chicken, rabbits and a single cow on the side. Nowadays, it is lettuce and lettuce again or one sees a forest of tomato plants" (Oudshoorn, 1964: 107).

3.3. Expansion of the new system (1965-1980)

The new greenhouse production system was further improved and refined in the 1960s and 1970s, The Wageningen Institute for Horticultural Engineering, for instance, set up a range of projects to elaborate the new guiding principles of mechanization and rationalization. In 1960, it investigated 'improved methods and organization in vegetable growing in greenhouses' (project no. 193). In 1965, it started projects that studied 'Mechanical pollination of tomato flowers' (project no. 259) and 'Transport systems in greenhouses' (project no. 265). And in 1966, new projects investigated 'Automated ventilation in greenhouses' (project no. 271) and 'Mechanization of vegetable growing in greenhouses' (project no. 273) (National Archives, no. 15).

The improvements in technical hardware, horticultural techniques and crop varieties resulted in major performance increases. Tomato productivity (kg/hectare), for instance, almost doubled between 1960 and 1980 (Figure 5).

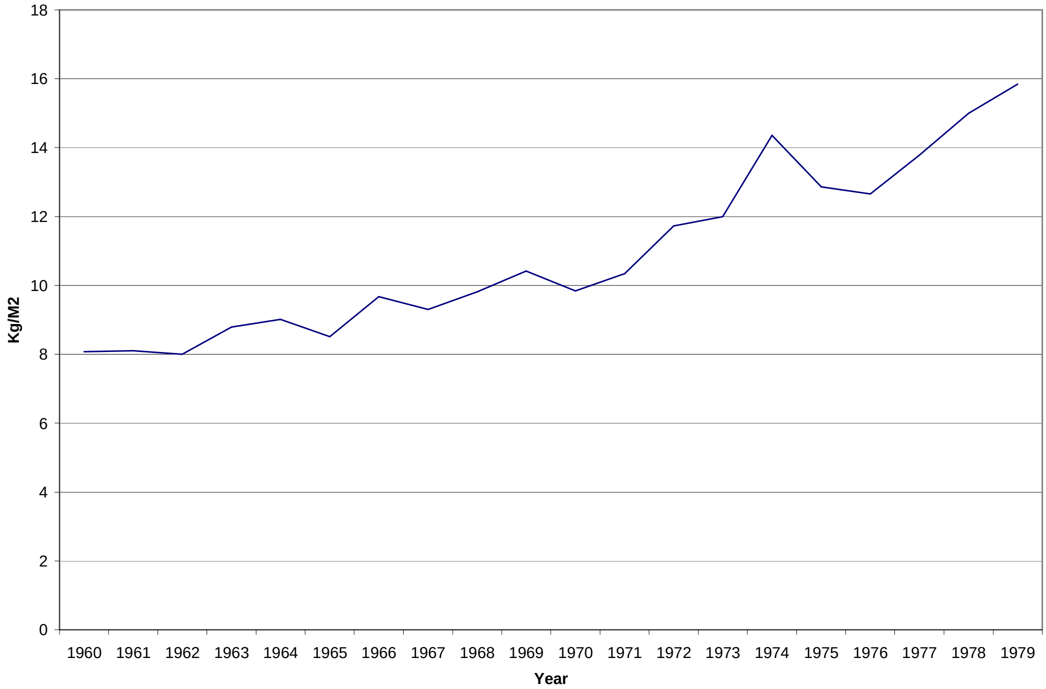

Figure 5: Increases in Dutch productivity and tomato yields (kg/m^2 per year) (data from the Food and Agriculture Organization,www.fao.org; accessed on 3-2-2008)

Relative production costs (guilders per kg) also decreased substantially, for tomatoes more than two thirds between 1954 and 1975 (Figure 6). Relative labour costs went down as technical improvements made it possible to work larger plots of land with the same personnel. Declining fuel costs made the largest overall contribution, especially after 1970 when cheap gas was supplied to greenhouse farmers (see below).[8]

[8] In 1982, fuel costs increased, because the second oil crisis (1979) pushed up oil prices. Although greenhouse farmers had long-term contracts with the Dutch Gas Union they were to some extent affected by this price increase.

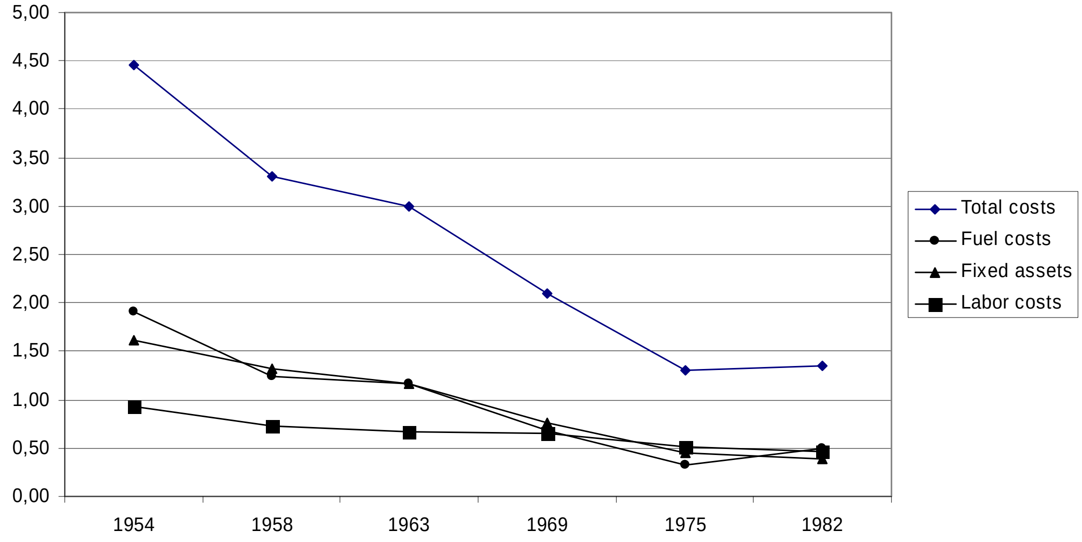

Figure 6: Relative production costs for tomatoes (1980 guilders/kg) (data from Buurma, 2001: 21)

The impressive cost/performance improvements boosted the international competitiveness of Dutch greenhouse farming, enabling Dutch crops to compete internationally with Southern European countries with more favourable climates.

The economic structure also changed, as improvements in technology and labour productivity stimulated scale increases in horticulture (Table 4).

	1960	**1970**	**1988**
Vegetables open air	0,66	1,51	3,13
Vegetables in greenhouse	0,26	0.41	0,70
Flowers in greenhouse	0,11	0,23	0,60

Table 4: Average size (hectares) of Dutch horticultural companies (Douw, 1990: 47)

These scale increases resulted both from an increase in the total area of greenhouse farming (see Figure 2) and a decrease in the number of firms (Table 5).

Year	**Number of firms**	**0.25 – 1 ha.**	**1 - 2 ha.**	**2 – 5 ha.**	**> 5 ha**
1972	10.262	8972	1151	131	8
1980	9.939	7408	2102	411	18
1991	9.474	6001	2690	716	67

Table 5: Size distribution of Dutch greenhouse horticultural firms (Vijverberg, 1996: 98)[9]

A drawback of the expanding greenhouse horticulture formed the increased soot and smog problems from artificial heating and fuel oil burning. Researchers therefore investigated alternatives, such as natural gas, which had cleaner burning properties and caused less air pollution and soot deposits. This research gained in credibility and relevance when major natural gas reserves were discovered in the North of the

[9] Reliable numbers about the number of firms are not available before 1970, because statistics do not differentiate between greenhouse and open-air horticulture (many firms had both).

Netherlands (in 1959), followed by the construction of a national gas infrastructure in subsequent years (Correljé *et al*., 2003).

The Institute for Horticultural Technology (IHT), the Dutch Gas Union, the Gas Institute, and manufacturers of gas burning technologies investigated if existing oil furnaces and boilers could be retrofitted to burn natural gas. Although technical results of gas burning (heat capacity, efficiency) were promising, cost-efficiency calculations showed that oil burning was cheaper than gas. The IHT confirmed this result in a report in 1966, which concluded that "across the board gas appears to be more expensive than oil" (National Archives, no. 15).

Nevertheless, the government developed a strategic vision in which greenhouse farmers would switch from oil to gas based heating (Van Doesburg *et al*., 1999). Because nuclear energy was expected to become the most important Dutch energy source, natural gas reserves had to be consumed in advance (Correljé *et al*., 2003). Further technical experiments in the late 1960s showed that gas burning not only reduced air pollution problems, but also facilitated CO_2 fertilization in greenhouses. This provided additional arguments for the shift to gas heating. The Dutch government, which was a major shareholder in the Dutch Gas Union, subsequently facilitated this shift by ensuring that gas tariffs to greenhouse farmers were substantially decreased:

> "To further boost the use of natural gas in horticulture and greenhouses, a special arrangement (1970) provided these users with low-priced gas. They were offered a much cheaper tariff than normal consumers. In a strongly coordinated campaign, the sector converted quickly to gas. By 1972 gas supplied around 50% of the sector's energy requirements. Particularly in western parts of the country, the reduction of oil use in greenhouses contributed to a decline in smog." (Correljé *et al.*, 2003: 66)

The supply of cheap gas lowered fuel costs (Figure 6) and stimulated the competitiveness of the export-oriented greenhouse horticulture. By 1976, the greenhouse sector used three billion m^3 natural gas per year (about 6% of total domestic consumption). Because of its economic success, the sector was seen as a showpiece of effective Dutch industry policy, which further legitimated government support.

Throughout the 1960s, greenhouse vegetable production increased in tandem with high economic competitiveness. While tomatoes remained important, other crops such as lettuce and cucumber were also increasingly grown in greenhouses (Table 6).

	1960	**1965**	**1970**
Tomatoes (millions of kg)	200	311	350
Cucumber (millions of pieces)	132	286	378
Lettuce (millions of pieces	300	470	566

Table 6: Auction supply of greenhouse vegetables (Vijverberg, 1996: 62)

Farmers could respond to changes in market demand by adjusting their production portfolio (shifting between crops). This was possible because the new greenhouse system was versatile and could be used alternatively for many crops.

After 1970, greenhouse farmers increasingly turned to flowers, laying the foundations for the internationally leading Dutch position in this premium market. Table 7 indicates this growing importance of flowers and plants.

Year	Total area of greenhouses	Area for vegetables	Area for cut flowers	Area for pot plants	Other (e.g. fruits)
1965	6339	5114 (81%)	863 (14%)	38 (0.5%)	4.5%
1970	7238	5374 (74%)	1440 (20%)	194 (3%)	3%
1975	7900	4683 (59%)	2608 (33%)	452 (6%)	2%
1980	8761	4508 (51%)	3275 (37%)	701 (8%)	4%

Table 7: Greenhouse area used for vegetables, cut flowers and pot plants, 1965-1980 (hectare) (Vijverberg, 1996: 65)

This relative shift was accompanied by a struggle between two regional clusters: specialized floriculturist in Aalsmeer and vegetable horticulturist in Westland (and Venlo). Since the economic crisis in the 1930s, the government had introduced production licenses for flowers, granting a monopoly to Aalsmeer farmers (Van Stuijvenberg, 1961). In the 1960s, Westland farmers began to contest these regulations, leading to a political struggle which involved three Westland agrarian organizations, the Floricultural Branch Organization, the central Dutch Agrarian Organization (HLO), and the government. After 1967, when the flower production licenses were abandoned, many vegetable horticulturalists switched towards the production of flowers.

3.4. Conclusions

The transformation in greenhouse horticulture was clearly not a breakthrough transition with one radical innovation driving the process. Instead, the transition followed a more gradual and stepwise reconfiguration path. *Multiple* component innovations were developed by universities, research institutes and technology suppliers, and subsequently adopted (and co-developed) in the greenhouse system. The incorporation of these innovations gradually transformed the architecture and practice of horticulture, changing it from craft-based farming that was dependent on natural conditions (sun, rain) into a vegetable factory suitable for year-round mass production of several products. The case study demonstrated that stepwise changes and gradual reconfiguration can indeed lead to major transitions and system changes, both in terms of farming practices and techno-economic performance criteria. While (most) existing farmers survived and enacted the transition, they had to acquire additional knowledge and competencies, through training and courses provided by extension services and technical experts. Young farmers acquired the new technical and business economics knowledge at horticultural schools.

Within the overall reconfiguration pattern, two additional patterns can be distinguished: 'straightjacket dynamics' and 'innovation cascades'. As new innovations entered the existing 'Westland greenhouse' design, certain problems prevented these innovations to reach their full potential. The Westland design thus increasingly functioned as a 'straightjacket': new innovations did not function optimally because they were pushed in the existing greenhouse design.

The Westland design was initially developed as a solution to soil dehydration, salinity and fertility problems. Farmers could not shift to closed ('Venlo') designs, until other solutions for these problems were developed. Because artificial soil flushing systems and new fertilizers provided such solutions, they facilitated the transition to the Venlo greenhouse design. We thus see an *innovation cascade* pattern in which different innovations build on each other: soil flushing systems + new fertilizers → shift to Venlo greenhouse design → diffusion of artificial heating and

CO_2 fertilization. While the reconfiguration path is generally more gradual than breakthrough transitions, these straightjacket dynamics and innovation cascades introduce jerks and jolts in the transition processes.

4. Network interactions and knowledge flows

To complement the preceding 'outside-in' analysis, this section makes an 'inside-out' analysis, focusing on the knowledge flows and social interactions that influenced the rapid adoption of innovations in Dutch greenhouse farming. We use the extended techno-economic network perspective from section 2 to analyze the networks and institutions that influenced the transfer of knowledge and innovations.

Techno-economic networks

The network ties *within* the horticultural community, i.e. the technology pole in Figure 2, were strong and deep, creating an economic cluster. To strengthen their negotiation position vis-à-vis buyers of fruits and vegetables, individual horticulturists created cooperatives in the early 20th century. In subsequent decades these cooperatives were extended to interactions with suppliers of seeds, fertilizer and equipment. In the late 1960s, the cooperatives also negotiated favourable gas supply contracts. While cooperatives were initially driven by commercial interest, they stimulated social interactions that helped create a collective identity and open attitude towards their own community (Vijverberg, 2004). This stimulated large horticulturalists, who often engaged in technical and scientific experiments (e.g. New Honsel), to share their experiences and knowledge with other farmers. The willingness to learn also led to the creation of horticultural study clubs, which organized meetings and courses in the winter-season. In the two post-war decades, 17 study groups were set up in the Westland area with more than 3000 members (Scholten en Sonneveld, 1999). In the early years, when technical issues received much attention, researchers and extension service officials were invited to give presentations. In the 1960s and 1970s, business economics issues also received more attention (cost/benefit calculations, investment decisions). The study clubs also set up experiments with new crop varieties and cultivation systems and organized excursions to innovative farmers and demonstration projects. The creation of the Dutch Federation of Horticultural Study Clubs, in 1964, signalled formal recognition of their importance for horticultural knowledge (Buurma, 2001). Official researchers from the experimental stations and Wageningen Agricultural University increasingly interacted with these study clubs, because their 'crop committees' provided valuable feedback on the basis of real-life testing (van Doesburg *et al.*, 1999).

The auction system, which was situated between the technology and market pole in Figure 2, further stimulated the collective identity of horticulturalists. These auction systems graded tomatoes (and other products) in terms of size and quality categories, without differentiating in terms of producers. Because products were thus sold *en bloc*, a collective interest emerged in product quality improvements (Vijverberg, 1996). This collective interest stimulated the willingness to exchange lessons and experiences.

The networks between research and farmers strongly influenced the innovativeness in Dutch horticulture. The so-called ERE-triptych (education, research and extension) indicates that education and extension were seen as important channels for the dissemination of scientific knowledge.

> "Transfer of knowledge, skills and technologies to the farming community was primarily a matter for the Agricultural Extension Service, the agricultural experiment stations and lower-level agricultural schools. A major function of the Wageningen school became providing competent agriculturists for these services" (Maat, 2001: 107).

In the post-war modernization ideology, the network relations in the ERE-triptych were seen as a linear model, with Wageningen Agricultural University producing new knowledge, which was subsequently transferred to farmers. In reality, however, and in line with recent insights about sectoral innovation systems (e.g. Malerba, 2002), there were mutual feedbacks and exchanges in this knowledge system. A distribution of cognitive labour emerged: a) researchers at universities and technical institutes (e.g. Institute for Horticultural Technology) developed theoretical knowledge, b) Horticultural Experiment Stations developed practical knowledge in test circumstances, and c) local farmers and horticultural study clubs produced real-life knowledge, based on experiences in a variety of concrete greenhouse practices. Instead of a one-way flow, the knowledge system was thus multi-sited with multi-directional interactions.

Knowledge flows also occurred via circulation of individuals (embodied knowledge) through the network. Researchers from the Dutch organization for Applied Scientific Research were, for instance, posted at the horticultural experimental stations in Aalsmeer and Naaldwijk (Scholten and Sonneveld, 1999). University researchers were sometimes posted with extension services. Research institutes paid for university chairs in particular areas, and university professors set up commercial research institutes. Maat (2001) therefore draws the following conclusion about the post-war period:

> "The organization of agricultural research in the Netherlands developed [...] into a layered structure, divided over the departments and laboratories of the Agricultural University, the research institutes and the experiment stations. (...) The research performed at the Agricultural University could present itself as fundamental without loosing its agricultural identity only when a clear relation was maintained with divisions that performed the more applied research" (p. 91-93).

Although the average greenhouse farmer did little R&D, these networks and interactions provided the whole sector with an effective innovation system.

Institutions

Regulative, normative and cognitive institutions also influenced innovation and knowledge exchange, leading to particular innovation patterns in greenhouse horticulture.

Many production and market *regulations* (e.g. guaranteed minimum prices, import and export restrictions, production licenses) were gradually abolished in the 1950s and 1960s, liberalizing production, trade and export. The creation of an open European market stimulated Dutch horticulture, which greatly depended on exports. The development and adoption of new technologies was stimulated through increased funding for the ERE-triptych and through propagation of a general vision of agricultural modernization. This vision was backed up with regulations and programs to stimulate investments in new technologies (e.g. bank guarantees for loans, regional development projects, Development and Buy Out Fund). Regulatory institutions thus encouraged rationalization, mechanization, scale increase, and modernization.

Important *normative* institutions were collective entrepreneurship (through cooperatives) and trust, which were stimulated by social ties that originated from intermarriage and kinship relations. Westland horticulturists did not see each other as competitors but as colleagues, part of collective enterprise. A Protestant work ethic further stimulated norms of hard work and a desire to improve (Defares, 1986; Vijverberg, 2004). A willingness to learn and share experiences further led to a collective innovation pattern for the Westland horticultural cluster as a whole.

A shared belief in the modernization vision was an important *cognitive* institution that stimulated knowledge exchange and the will to invest. Knowledge exchange was also promoted by a congruence in mindsets between farmers and university researchers (who often came from farming families). Researchers therefore often had intimate knowledge of concrete farming practices (Van den Brink, 1990). Many horticulturalists, however, had ambiguous attitudes about science. On the one hand, they recognized the importance of research for generating new findings. On the other hand, they were sometimes sceptical, down-to-earth and not easily persuaded by purely theoretical arguments (e.g. about the need to adopt particular innovations). This tension led to an innovation pattern with much emphasis on demonstration projects and concrete experiments (in horticultural experimental stations or study clubs). An additional reason for the importance of experimentation was that greenhouses were a 'configurational technology' (Fleck, 1994), where the challenge was to get multiple components to work together. While individual components could be tested in a research laboratory, learning about their alignment in greenhouse systems could only occur through concrete implementation. The greenhouse thus became a laboratory in it self, where experimentation and ‘learning by trying’ (Fleck, 1994) were important. The horticultural innovation pattern thus had characteristics of 'vicarious experimentation', one of three types of experimentation patterns Leonard-Barton (1995) distinguishes (Figure 7).

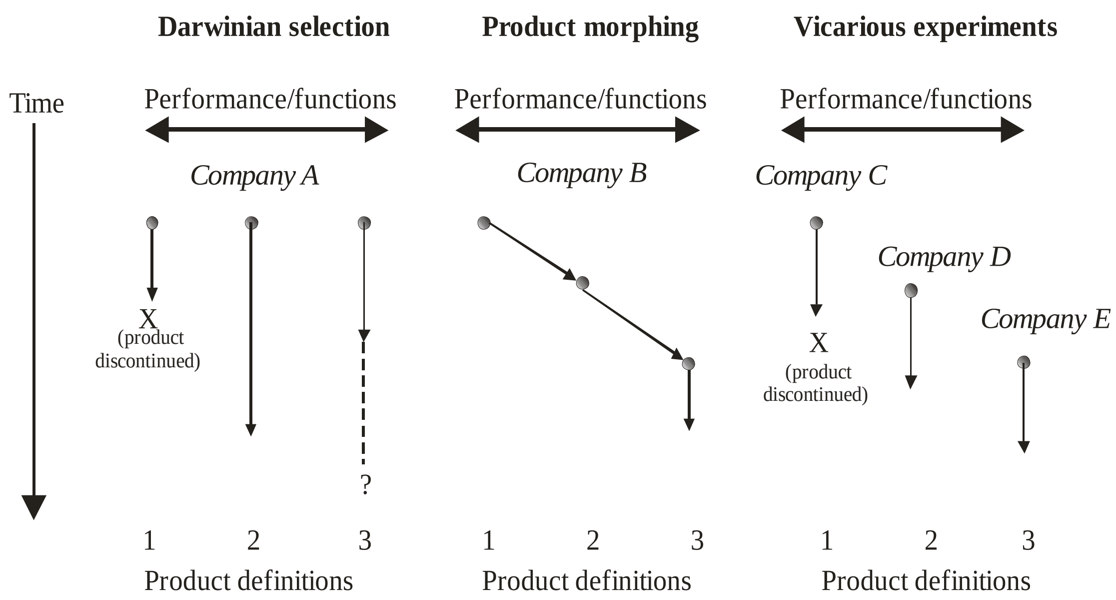

Figure 7: Three experimentation strategies (Leonard-Barton, 1995: 208)

In vicarious experimentation, innovation consists of cumulative experimentation projects that constitute a learning trajectory. Firms exchange experiences and learn from each other's experiments, thus contributing to 'collective invention' (Allen, 1983). This innovation pattern deviates from Darwinian selection, in which a single company exposes a variety of product designs to market selection, and from product morphing, in which a single company engages in sequential market experimentation projects and uses the feedback to learn and improve the product.

5. Conclusions

This article has shown that transitions and system innovations do not only come about through discontinuous breakthrough innovations. Stepwise reconfiguration is another transition path, which is more likely in distributed systems where multiple components act together. The article elaborated three characteristics of reconfiguration transitions: 1) reconfigurations involves *multiple* component innovations, 2) these innovations are initially incorporated into the existing system as add-on or component replacement, and subsequently trigger adjustments that change the relations between components and the system architecture, 3) incumbent actors survive and enact the process. Because they adopt innovations, which are initially developed elsewhere, knowledge and innovation flows are important. With regard to this last characteristic, the article extended the techno-economic network approach with institutional theory.

The 'outside-in' analysis of the case study demonstrated the empirical relevance of the first two characteristics, and found two additional patterns in reconfiguration processes: 'straightjacket dynamics' and 'innovation cascades'. The 'inside-out' analysis of networks and institutions further explained the speed of the transition in Dutch greenhouse horticulture, which developed into a competitive world leader in vegetables and flowers.

The case study also shows that so-called 'low-tech' sectors (such as agriculture) are shot through with innovation dynamics. This is a reminder for innovation studies, where most work still focuses on high-tech sectors. In that sense, the article adds to the (still small) literature that extends innovation studies' insights to domains such as retailing, services (Miles, 2000), traditional manufacturing, banking (e.g. Nightingale and Poll, 2000).

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3. A multi-paradigm analysis of the transition from mixed farming to bio-industrial pork production (1930-1980)

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Abstract:
This article distinguishes five ontological paradigms based on different assumptions about causal agents and primary causal mechanisms. These paradigms are: rational choice, conflict and power struggle, interpretivism, functionalism, and structuralism. Adding to the literature on sociotechnical transitions, the article makes a multi-paradigm analysis of the Dutch transition from mixed pig farming to bio-industry. The article provides five explanations of this transition and analyses strengths and weaknesses as well as crossovers and complementarities between paradigms.

1. Introduction

This article makes empirical and theoretical contributions to the literature on sociotechnical transitions and system innovations (Rohracher, 2001; Geels, 2002; Smith *et al*., 2005; Geels and Schot, 2007). Empirically, the article contributes a new case study: the Dutch transition in the production and consumption of pigs. The number of pigs increased from 2 million in 1930 to 14 million in 1990, making Netherlands the biggest European net exporter of pork (Figure 1). Dutch pork consumption also increased substantially (Figure 2).

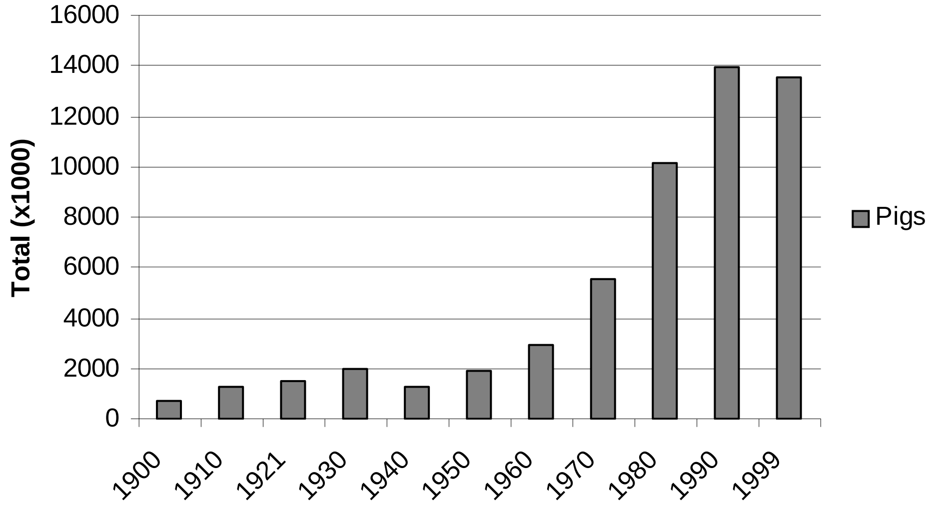

Figure 1: Number of Dutch pigs (data from the Central Bureau of Statistics)

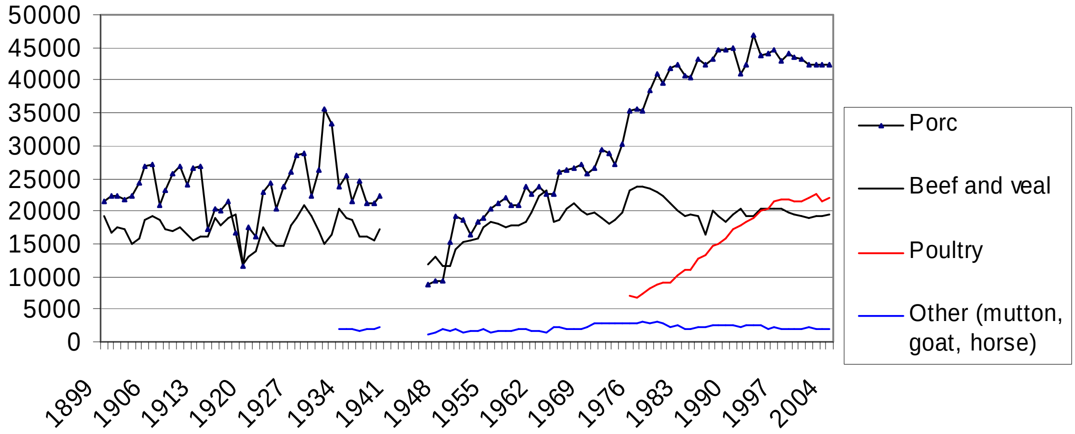

Figure 2: Dutch meat consumption per capita per year (in grams) (data from the Central Bureau of Statistics)

The transition not only involved farmers and consumers, but also a range of other actors in the pork chain. Table 1 provides an a-historical indication.

Sub-system	**Activity**	**Actor**
Supply	1. Compound feed	Compound feed companies
	2. Stables, buildings	Stable construction companies
	3. Technological components (food supply systems, heating)	Supply companies, compound feed companies
Primary production (pig farming)	4. Breeding	Pig breeding farms, herdbook organizations and breeding associations, artificial insemination organizations
	5. Fattening	Pig farms
Meat processing and distribution	6. Slaughtering	Slaughterhouse, meat processing companies
	7. Meat processing	Meat processing companies
	8. Distribution and trade	Meat wholesalers, butchers, supermarkets
Waste disposal	9. Corpse processing	Destruction companies

	10. Manure processing	Pig farms, manure distribution companies, manure digestion companies.
Consumption	11. Buying, consumption	Consumers, consumer organizations
Services	12. Finance	Banks, insurance companies, accountants, book keeping organizations
	13. Education	Agricultural schools and universities
	14. Research	Government research institutes, Agricultural University Wageningen, test stations, experimental farms, agri-food industry
	15. Advice, extension	Branch organizations, government extension service, national farmers associations, feed companies, banks.
	16. Health care	Veterinarians, animal health inspection service

Table 1: Phases and actors in the pork chain (Termeer, 1993: 55)

The literature provides different explanations of this transition. Some explanations emphasize economic processes such as rising consumer incomes, market competition and innovation races amongst farmers, which stimulated them to shift towards mechanization, specialization, and large-scale operation. Another explanation highlights the influence of the state and farmer's associations, who developed and implemented a vision to modernize agriculture. Yet other explanations emphasize learning processes and local projects, or changes in the pork chain such as increasing influence from specialized feed suppliers and supermarkets.

To understand this variety of explanations, the article makes theoretical contributions that relate to foundational ontologies. Ontologies are not about specific theories, but about the underlying assumptions scholars make about the nature of the (social) world and its causal relationships. Ontologies postulate a certain causal agent and primary causal mechanism. "(…) causal mechanisms are treated as ontologically primitive causes of outcomes and associations; they are original movers or 'ultimate causes'" (Mahoney, 2004: 461). Table 2 distinguishes five ontological paradigms.

	Rational choice, utilitarianism	**Power struggle, conflict**	**Interpretivism (social constructivism)**	**Functionalism (systems theory)**	**Structuralism (cultural deep structures)**
Causal agent	Individual actors	Collective actors with conflicting interests	Individual actors	Social system	Collectively shared cultural assumptions, repertoires
Causal mechanism	Choice and instrumental rationality, cost-benefit calculation.	Conflict and power struggle	Semiotic practices, sensemaking, learning	Integration of sub-systems and fulfilment of system needs	Deep structures influence actors 'behind their backs' (taken-for-granted)

Table 2: Typology of ontologies (adapted and expanded from Mahoney, 2004: 463)

These ontologies differ with regard to contrasting assumptions on two dimensions. The first dimension is the nature of reality: a) objectivity assumes an external reality of deterministic and predictable relationships, b) subjectivity assumes contextually bound and fluid social constructions. The second dimension is the problem of order (individualist-collectivist): a) macro-scholars assume that order is externally created by collective phenomena, b) micro-scholars assume that order has an individual basis and arises from micro-interactions. Figure 3 shows the position of different ontologies in the resulting 2x2 matrix.

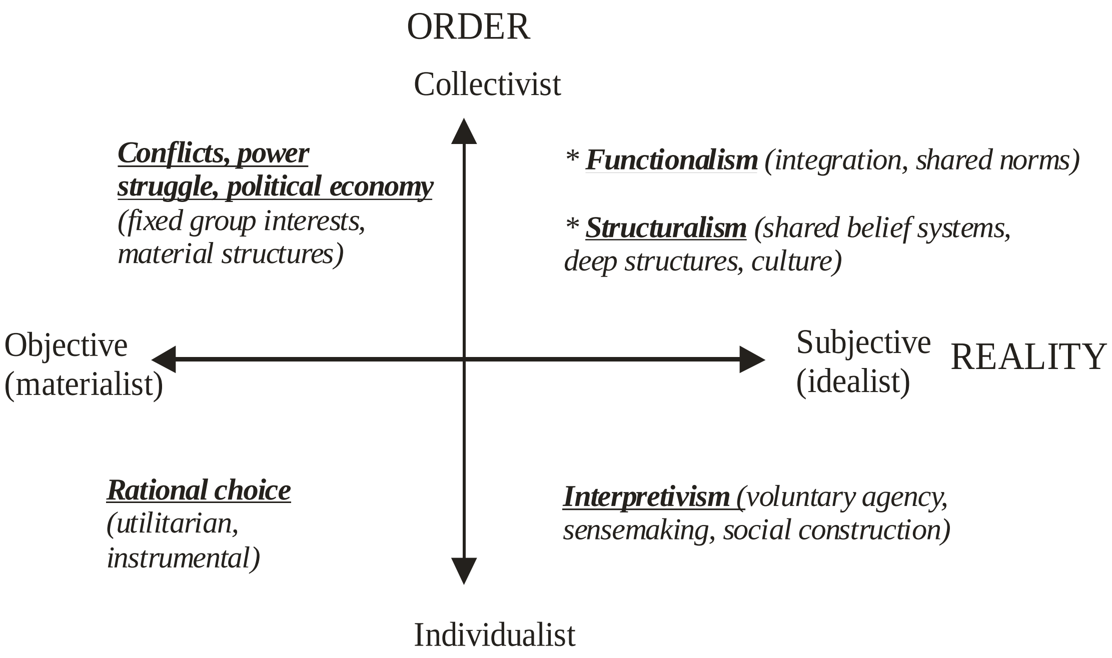

Figure 3: Sociological ordering of ontologies (adapted from Gioia and Pitre, 1990)

Functionalism and structuralism are similar in some basic assumptions, understanding reality as socially constructed and ordered by collective phenomena. They differ, however, in precise mechanisms, with structuralism highlighting shared belief systems and functionalism highlighting functional integration (and alignment of roles and behavioural norms).

These foundational ontologies are often seen as incompatible and incommensurable. Recently, however, scholars have started to work on multi-paradigm analysis, exploring combinations and crossovers (Gioia and Pitre, 1990). Lewis and Grimes (1999) distinguish three types of multi-paradigm analysis: 1) multi-paradigm review, which juxtaposes insights from different paradigms, recognizing divides and bridges in existing theories, 2) multi-paradigm research, which applies divergent paradigm lenses empirically, showing how concrete cases can be interpreted differently, 3) meta-paradigm theory building, which strives to combine and link different paradigm insights in a novel and more holistic understanding. This article practices the second kind of multi-paradigm analysis, providing and analyzing different explanations of the pig farming transition.

The research question is: how do different foundational paradigms explain the transition in pig farming and consumption? To answer this question, the article uses secondary sources, especially from agricultural history, food history, and history of technology. A further reflexive question is: Are these different explanations incommensurable or do connections exist? Section 2 provides further empirical delineations of the pork transition. Section 3 provides five explanations, each from a different ontology. Section 4 addresses the reflexive question, and provides analyses and conclusions.

2. Empirical delineation of the pig transition

During the transition, major changes occurred in the economic structure as the number of farms with pigs decreased with 80% (Table 3). The average number of pigs per farm rose from 20 in 1960 to 476 in 1990, signalling major scale increases.

	1960	**1970**	**1975**	**1983**	**1987**	**1990**
Number of pigs (million)	3	5.5	7.3	10.7	14.3	13.9
Number of pig farms (x 1000)	146	76	55	38	35	29
Average number of pigs per farm	20	73	132	282	406	476

Table 3: Developments in pig farming (Termeer, 1993: 56)

	1965	**1970**	**1980**	**1990**
Breeding				
Number of piglets per birth per sow	8.9	8.7	8.5	9.3
Number of births per sow per year	1.66	1.72	1.85	2.20
Number of piglets per sow per year	14.8	15.0	15.7	20.5
Average deaths of piglets per sow/year (percentage of total births)	3.9 (26%)	3.6 (24%)	2.7 (17%)	2.1 (10%)
Fattening				
Weight growth (grams /day	547	563	610	719
Food uptake (kg/day)	1.99	1.95	2.04	2.07
Food conversion (kg food/kg growth)	3.64	3.47	3.4	2.88

Table 4: Technical performance improvements in pig breeding and fattening (Groenestein, 2003: 3)

Economic pig performance improved substantially during the transition (Table 4). The yearly number of piglets a sow produced increased from 15 in 1965 to 22 in 2000. Breeding research played an important role in these improvements. Population genetics, heritability data and mating systems analysis enabled the use of statistical analysis to enhance valuable traits through intensive selection and inbreeding (Boyd, 2001). Artificial insemination, which enabled breeding with champions, also improved results.[10] Improvements also came from the introduction of a new practice, namely separating baby pigs from the sow within a few days of birth. With no need for suckling, the sow could be bred again within just nine weeks (Finlay, 2004). The young piglets were fortified with antibiotics and vitamins, and kept in artificially heated environments. New stable designs, which made it less likely for sows to crush their offspring, also contributed to reduced numbers of yearly piglet deaths per sow.

In pig fattening, food uptake and food conversion rates (kg. food needed per kg growth) increased substantially, because of improved breeding techniques and specially designed food. In the mixed farming regime, pigs searched their own food on farmyards or were fed leftovers (potatoes skins, skimmed milk, kitchen waste). During the transition, pig farmers came to rely on concentrated feeds, which were based on research into nutrition, digestion, and physiological needs. Specially

[10] Early experiments with artificial insemination for pigs began in the late 1950s. Fertilization results were mixed, ranging between 28 and 76%, which was lower than normal fertilization (Paridaans, 1987: 205). Treatment and conservation of sperm and the right timing of insemination were difficult issues that required further research. By 1963, average fertilization results had increased to 58% and in 1969 to 78%. Subsequently, the number of artificial inseminations increased rapidly, from 23.764 in 1969 to 41.375 in 1975 to 172.851 in 1985 (Paridaans, 1987: 208) (data refer to the Province of North-Brabant, where most pig farming concentrated).

designed food had ideal ratios of nutrients such as fats, proteins, carbohydrates, minerals, vitamins amino acids (Groenestein, 2003.

The shape of pigs also changed during the transition. In the 1930s, when consumers appreciated fat, breeding focused on *fat* pigs. Pigs would be fattened up to 150 kg before they were slaughtered. In the 1960s, when consumer preferences shifted to lean meat, the animal's physiology was changed through selective breeding, resulting in 'meat-type' hogs with reduced back fat measurements. These pigs were sold, when they weighed around 100 kg. The new pigs, which emerged from breeding research, also grew more uniformly, more consistently, and more predictably (Finlay, 2004). The standardized pig shapes fitted better with the specifications of slaughtering machines. Pigs were also physically adjusted to fit the bio-industry environment: tails were cut off to prevent ‘cannibalism’ and tail biting, which resulted from boredom in small confinements; male piglets were castrated at birth, because sex hormones influenced meat tastes as they grew older; teeth were commonly clipped to protect the sows' nipples and reduce damage from biting.

The transition from mixed farming to specialized bio-industry entailed a range of changes in pig farming practices.

* The bio-industry transition implied the end of mixed farming, as farmers specialized and focuses on one particular product. On mixed farms, pig farming co-existed with other activities. Most farmers held some cows and worked small plots of land to produce potatoes, corn, or legumes. Because pigs ate leftovers, they acted as 'garbage cans' that earned additional incomes (Somers, 1991). During the transition, pigs changed from side-activity to core business.
* The bio-industry transition entailed a shift from outdoor pastures to confined animal husbandry systems. In these big sheds, pig farming occurred on an industrial scale, focusing on productivity and throughput. These sheds used new technologies such as automatic water supply and feeding systems, large food storage silos, electric lights, air conditioning, artificial heaters, germicidal lamps (to prevent fungus and infections). To construct these housing systems, farmers came to rely on specialized suppliers (Finlay, 2004). Stable designs also changed. Fattening pigs were confined to small cells and lived on concrete floors, which were easy for farmers to clean. As stables grew larger, manure removal became problematic. Technology offered a solution in the form of grates and underlying sloped floors, which led manure to storage cellars. Breeding sows had somewhat bigger cells to limit the risk of crushing piglets. Sows and piglets also had some straw in their stables to improve comfort.
* With the change to indoor confinements and crowded living conditions, pigs became more susceptible to disease. Sanitation and disease control thus became more important. The intermittent cleaning of stables with lye and creosote made farmers dependent on the chemical industry. Farmers also used increasing quantities of antibiotics, which not only decreased diseases, but also stimulated growth. This unexpected effect was discovered in the late 1940s, although the causal mechanisms remained unclear (Finlay, 2004). The use of antibiotics in animal feed led to more uniform growth, improved weight gain, and enhanced feed-conversion efficiency (increases of about 5%). In the 1990s, the use of antibiotics became controversial, because certain viruses and diseases developed resistance to antibiotics, creating public health risks (Boyd, 2001).
* In mixed farming, pigs were fed leftovers from arable production. During the transition, pig farmers came to rely on commercial feed manufacturers which imported high-energy fodder from around the world. This eliminated the need for

pasture, and uncoupled pig farming from the land. Farmers only needed a small plot of land to build animal husbandry systems.
* Pig farming used to follow the seasonal cycle and the availability of crops from the land. Farmers typically bred their hogs in the fall so that piglets would be born in the spring. In the summer and fall, pigs fed on pastures. In late fall, pigs were slaughtered, causing an annual oversupply that depressed prices (Finlay, 2004). This supply cycle meant that fresh pork was only available during certain parts of the year. The shift to manufactured feeds and indoor housing systems changed this seasonal cycle into a continuous flow pattern that ensured a steady supply of fresh meat.

These changes transformed pig farming into ‘agri-business’, a network activity with multiple interdependent chains. Pig farming was increasingly dependent on technology suppliers, pharmaceutical industry, feed companies, chemical industry, banks, and extension services.

3. Explanations from five foundational paradigms

The subsequent subsections first delineate the basic assumptions and mechanisms of different ontologies and then provide explanations of the bio-industry transition.

3.1. Rational choice: Prices, factors costs, investments

General paradigm
The rational choice paradigm, which is based on methodological individualism, assumes that the basic agents are individuals with clearly formulated (material) interests and preferences. Actors use instrumental rationality and procedures (e.g. cost-benefit calculations) to choose between alternative courses of action. Neo-classical economics is the prime example.

With regard to transitions, core explanatory elements are sales prices, factor costs, adoption decisions, investment decisions, strategies and pay-off rates. Producers compete with each other through price and performance of products. To increase market shares and profits, firms strive to lower the costs of input factors (e.g. labour, land, inputs, capital). Transitions in production technology, such as the shift to bio-industry, depend on capital investments. Such decisions depend on calculated return on investments and the availability of capital (borrowing from banks, interest rates, etc). Farmers who invest in new production technology enhance their productivity and economic performance. They will subsequently. The population transforms, because fit firms survive and push 'weaker' firms off the market. Transitions thus come about through competition, investments and market selection.

Explaining the bio-industry transition
On the demand side, rational choice theories highlight the role of rising incomes, which increased with almost 300% between 1950 and 1980 (Figure 4).

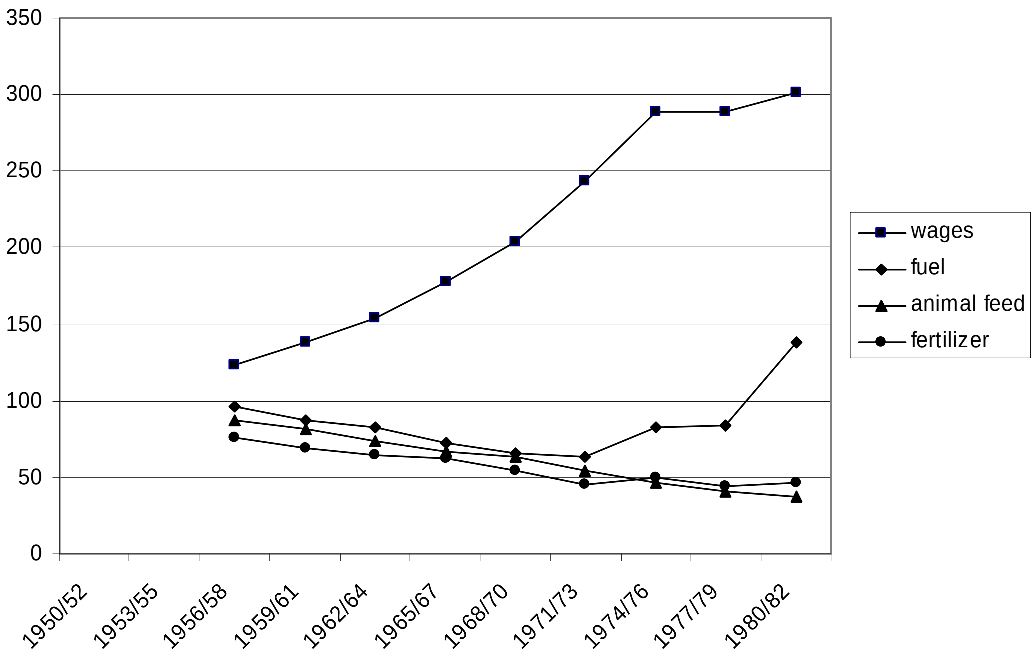

*Figure 4: Three year average, real (inflation-adjusted) price index data for wages and factor costs (1949/50-1952/53 = 100) (*Van der Weijden *et al*, 1984: 18)

Increasing wages, especially after 1965, enabled consumers to buy more meat, especially pork, which was generally cheaper than beef. On the supply side, rational choice theories explain farmers' choices to invest in bio-industry technologies with factors such as labour costs, fodder prices and sales price of pigs. Rising wages led to higher labour costs, which formed a general incentive to shift from labour to capital. Seasonal workers, who assisted farmers during busy periods, were fired. But for pig farming, labour costs were less important than food costs, which accounted for 40-60% of total costs. Decreasing animal feed prices in the 1950s and 1960s formed an important incentive for scale increase in pig farming (Figure 4). The decrease of relative prices of agricultural products formed another incentive for scale increase. Because labour value per pig per year decreased (Table 5; not corrected for inflation), farmers with constant output, would earn less money. This was an incentive for farmers to shift to large-scale pig farming.

	Sales price (guilders) per kg. pig	Food price (guilders/ 100 kg)	Sales price per pig per year	Costs (excl. labour) per pig per year	Labour value (guilders) per pig per year
1956/57-1960/61	2.13	33.00	415	360	55
1961/62-1965/66	2.37	34.50	477	420	57
1966/67-1970/71	2.84	38.70	557	508	49
1971/72-1975/76	3.33	45.80	705	648	57
1976/77-1980/81	3.63	53.70	799	764	35
1981/82-1985/86	4.15	61.30	971	914	57
1986/87-1989/90	3.30	51.70	827	799	28

Table 5: Economic results in pig farming, five year averages (not corrected for inflation) (Dröge et al, 1990: 78)

The changing factor costs and pig prices formed economic incentives for specialization and increasing scale. Innovative farmers made investments in confined housing systems, feeding systems, lighting and heating systems, etc. Agricultural banks provided credit. The Rabobank, which emerged in 1972 from a fusion between the Cooperative Central Farm Credit Bank and the Central Raiffeisen Bank, provided about 90% of all agricultural loans. The speed of investments accelerated in the 1970s. Between 1974 and 1980, at the height of expansion, agricultural loans (in all sectors) increased from 7 to 20 billion guilders per year (Van der Lans en Vuijsje, 1999: 115).[11]

The bio-industry transition was also stimulated by the creation of bigger markets. Following the Treaty of Rome (1957), the Common Agricultural Policy (1958) created a European market that was characterized by: a) free trade between member countries, b) common preference: agricultural products from member countries were treated preferentially, and c) financial solidarity: each member state paid for the CAP (De Groot *et al.*, 1990). Dutch agriculture and pig farming, which had always been oriented towards exports, took advantage of this opportunity and conquered large market shares. Economies of scale provided a self-reinforcing mechanism. Farmers with larger stables had lower production costs per pig, and could conquer bigger market shares. This increased their turnover, and enabled them to invest in bigger stables. Farmers who changed their practices through investments and adoption of 'modern' technologies survived, while others gradually disappeared through market competition.

3.2. Conflict and power struggle: Powerful actors implement their vision

General paradigm

In the paradigm of conflict and power struggle collective actors are key causal agents. These actors are assumed to have conflicting goals and interests. Hence, the main causal mechanism is conflict and power struggle. While Marxism focused on classes (labour versus capital), later institutional theories highlighted government agencies, branch organizations, special-interest groups and other collective macro-actors. Power is a multi-faceted phenomenon, which can be overt (e.g. force, police suppression, threatening) or operate through subtler mechanisms (e.g. authority, knowledge, agenda-setting). Stability arises from powerful groups or elites, who protect their vested interests against challengers. Change and transitions result from shifts in the balance of power, i.e. the weakening of elites or the strengthening of challengers.

In rural sociology, neo-Marxist scholars used political economy considerations to understand rural transformations (Goodman and Redclift, 1981). They highlighted conflicts between agrarian capitalists and local farmers, the influence of agribusiness and the facilitating role of the state. Power struggles or coalitions between collective actors influence the regulations, financial incentive structures, and subsidies that frame economic processes.

Explaining the bio-industry transition

The three National Farmer's Associations (NFA), who acted on behalf of the agricultural sector, were one powerful collective actor in agriculture. The NFA's had good contacts with local farmers through their regional and local branches, which organized study clubs, distributed information, published magazines, and organized

[11] 1 guilder = 0.45 euro.

courses. The government was another collective actor. In the early 20th century, the government only influenced agriculture through funding schools, research and extension services, i.e. the so-called ERE-triptych (education, research and extension). Government involvement increased strongly in response to the economic crisis of the 1930s. The government established minimum prizes to cover production costs for farmers (Bieleman, 1992). To combat over-production and decreasing prices, the government also set production restrictions, e.g. on pig, cattle and poultry. To protect the domestic market, the government established levies for agricultural imports. To protect small farms, who suffered most from the Depression, the government established the Agency for Small Farms (ASF) in 1936. The scale of government support was massive. Between 1933 and 1936, total expenditures of the Agriculture Crisis Fund were 200 million guilders per year (Bieleman, 1992: 238-239). This accounted for almost 40% of total agricultural income.

This intervention resulted in the creation of the 'green front', a corporatist coalition between the NFA's, political parties in Parliament, and the Ministry of Agricultural and Fisheries, which was created in 1935 (Louwes, 1980).[12] Further institutionalization occurred with the creation of the Foundation for Agriculture (1946), where the NFA's consulted with the Ministry. Its successor, the Agricultural Board (1954), also performed executive tasks for the government, e.g. providing advice to farmers, making sure that members obliged laws and regulations. The institutional arrangements also extended into politics, with some members of the Agricultural Board being members of Parliament. The 'green front' was a strong, corporatist coalition, which protected and supported agriculture.

In the post-war period, this corporatist coalition developed a new vision of agricultural modernization, which was subsequently implemented by influencing the economic institutions. Post-war agricultural policy had four general aims (Louwes, 1980; De Groot and Bauwens, 1990): 1) Food security: reliable and sufficient food supply ('no more hunger'), 2) Cheap food supply: low food prices would allow low wages, which would stimulate industrialization, 3) Reasonable incomes for farmers (guaranteed livelihood), 4) Increased export, so that agriculture would improve the national balance of payments.

During the first six-year plan (1947-1952), the emphasis was on the first and second aim. Rationalization was intended to increase production (Van den Brink, 1990). Rationalization included land redistribution, intensification of the farm plan (doing multiple tasks with the same land) and expansion of the ERE-triptych aimed at dissemination of scientific practices to farmers. The government created several new research institutes: the Agricultural Economics Research Institute (AERI) was created in 1947 to perform economic research and act as agricultural planning bureau. The Institute for Agricultural Technology and Rationalization was created in 1949; the Institute for Animal Husbandry Research in 1951; the Institute for Agricultural Buildings and Constructions in 1957, the Institute for Soil Fertility Research in 1957. Education and extension services were also expanded. The number of employees at the Agricultural Extension Service tripled, from 500 in 1946 to 1420 in 1950 to 1580 in 1956 (Zuurbier, 1984). Employees gave presentations for farmers, visited study clubs, distributed reports, and organized excursions to model farms. Between 1940 and 1960, the number of schools and students also increased rapidly, often operated by NFA's and subsidized by the government (Table 6)

[12] Agriculture previously fell under the Ministry of Labor, Trade and Industry.

	Number of NCB schools	Number of students
1922	2	127
1930	7	487
1940	10	1052
1950	39	3475
1960	48	3049
1970	23	1734
1980	11	3019
1990	8	2212
1994	6	2049

Table 6: Number of agricultural schools operated by the North-Brabant Christian Farmers Organization, one of the NFA's (Duffhues, 1996: 404)

The expansion of the ERE-triptych created a social network that disseminated 'rational' and 'modern' knowledge to farmers, with the aim of influencing their attitudes and practices.

High world agricultural prices in the immediate post-war years, threatened the second policy aim (cheap food supply). Hence, the government set maximum prizes for agricultural products that were below world prices. They compensated farmers for the difference. In the early 1950s, however, world agricultural prizes began to decrease, threatening the livelihood of farmers (third policy aim). To protect farmers, the government reinforced import levies and set minimum prizes, which formed indirect subsidies. The level of these fixed prices was determined in yearly negotiations between the Ministry and NFA's (Van den Brink, 1990). These negotiations were based on average production costs, increased with a profit margin, as calculated by AERI. With guaranteed minimum prizes, production increased rapidly.

By the mid-1950s, agriculture began to produce surpluses, thus realizing the first aim (self-sufficiency), but at increasing costs for the government. As national incomes began to increase, the second aim (cheap food) became less important. The third aim became more important, however, because agricultural incomes lagged behind other sectors. To improve agricultural incomes, the government wanted to improve the labour productivity of existing farms, e.g. through mechanization and reduction of hired labour.

In the late 1950s, the government developed a new vision of 'structural adjustment', which aimed at changing the economic structure: small farms should disappear and make way for large-scale, modern farms (Van den Brink, 1990). This vision implied a new interpretation of the third aim: reasonable incomes were not stimulated for *all* farmers, but only for farmers who were willing to modernize, mechanize and increase the scale of operation (De Groot and Bauwens, 1990). This vision also gave more emphasis to the fourth aim (increased export and contribution to national income). The NFA's did not immediately accept this new vision. By the early 1960s, however, the 'green front' achieved consensus and developed policy instruments to implement this new vision.

One instrument was the setting of fixed prices at a level that allowed economically viable operation only for large firms. Hence, AERI's calculations of average production costs were increasingly modelled on *desired* large-scale farms with new production technologies (Van der Ploeg, 2001). Price instruments became increasingly selective and tailored to the survival of large farms. Economic life for small farms thus became harder.

Another instrument was the expansion of land consolidation projects, which favoured the creation of larger farms in arable farming (lower part of Figure 5). Although this instrument had less immediate impact on pig farming, it indicates the massive scale of government involvement in agriculture. In 1970, the government spent almost 5% of the gross national product on different agricultural structural adjustment policies (Van den Brink, 1990: 11). Between 1947 and 1985, investments amounted to 13.8 billion guilders (Van den Bergh, 2004: 171). Land consolidation projects also entailed government investments in infrastructures such as smoothening land surfaces, improving canals and drainage ditches, constructing regional roads, piped water and electricity infrastructures. The expansion of electricity and piped water systems facilitated the operation of new housing systems in pig farming (Karel, 2005: 251).

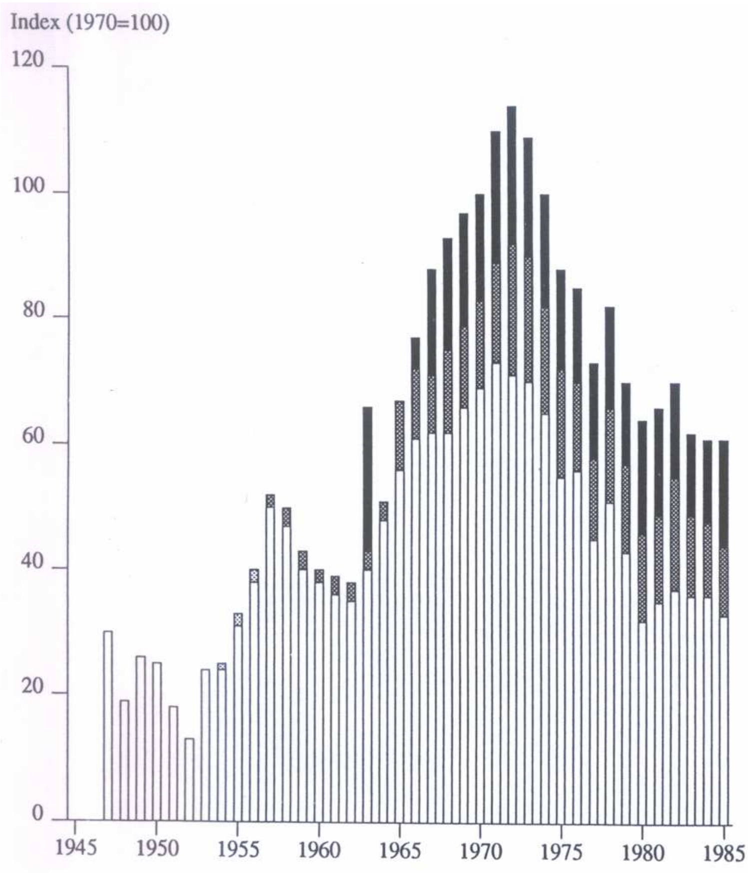

Figure 5: Indexed developments of government expenditures on structural adjustment policies: Land consolidation and improvement (white), land purchase (grey) and the Development and Buy-Out Fund (dark) (Van den Brink, 1990: 11)

Regional improvement projects formed another structural adjustment instrument, targeting not individual farms but entire villages and regions. These projects subsidized the introduction of new technologies and the rationalization of farms. After two pilot projects (1953-1956), the number of projects increased rapidly (Figure 6). The extension service organized trips to these projects to convince farmers of the success of modern practices and new technologies. Around 71.000 farms, about 35% of the farmer's population, were involved in the 132 regional improvement projects between 1956 and 1973 (Karel, 2005: 330).

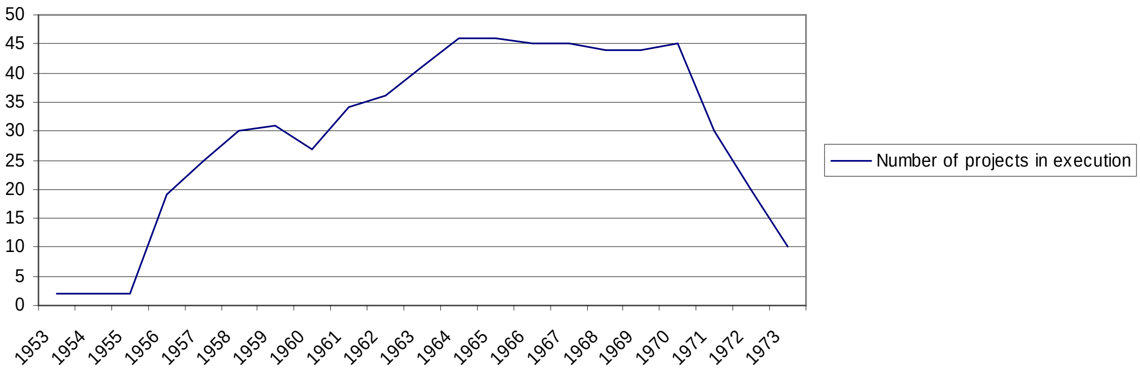

Figure 6: Number of regional improvement projects (data from Karel, 2005: 124)

Early projects were about the improvement of *existing* small farms. After 1963, projects increasingly focused on scale increases of innovative farmers and the reduction of small farms that did not innovate (Karel, 2005). The decline of small farms was further stimulated by another instrument: the Development and Buy Out Fund (Van den Brink, 1990). This Fund, created in 1963, provided subsidies not only to farmers who were willing to expand but also to farmers who discontinued operation (upper part of Figure 5). The different policy instruments increasingly worked in the same direction, stimulating modernization, mechanization, rationalization, and scale increase.

The agricultural modernization policies were not uncontested. The 'Free farmers movement', which emerged in the mid-1950s, opposed the increasing government interference and worsening conditions for small farmers (Nooij, 1969). They created a political party, the Farmers' Party, which acquired three seats in Parliamentary elections in 1963, and seven seats in 1967. Despite public support, the Farmers' Party had little influence and could not alter agricultural policies. Although the Farmers' Party attracted much publicity, the scale of farmers' protest was relatively small compared to the decimation of rural populations. An Italian rural sociologist expressed surprise that the government’s Long-Range Plan for Land Consolidation (1958), which aimed to reduce the number of farms with more than 50%, did not lead to bigger rural protests (cited in Van der Ploeg, 2001: 298). One explanation is that farmers, who went out of business, were financially compensated. Another explanation is that Dutch farmers were relatively docile towards authorities (Duffhues, 1996). The support of NFA's for the government’s plans (since the early 1960s) also created legitimacy, which many local farmers respected.

Criticism also came from members of Parliament and economic experts, who questioned the rationality of massive agricultural investments (De Groot and Bauwens, 1990). But these criticisms were ignored or sidelined by the ‘green front’, which acted like a 'state within the state'.

Special-interest groups, which represented new societal values such as animal welfare and the environment, also criticised pig farming. The action group 'Nice Animals' (‘Lekker Dier’) and the Foundation for Nature and Environment criticized the bio-industry for poor living conditions of pigs, water and soil pollution from manure surpluses, and stench problems (Crijns, 1998). These criticisms were neglected or denied, because they came from agricultural outsiders. Internal criticisms about these issues were silenced with the exercise of overt power. In 1972, for instance, the Agriculture Ministry prevented the publication of a research report from the Institute for Animal Husbandry Research (1972), which noted that pigs were biting each other's tails and ears, because of boredom and stress that were related to confinement in small spaces (Crijns, 1998). With regard to manure problems, the Agriculture Ministry frustrated and delayed the introduction of structural solutions for 12 years (1972-1984). In the early 1970s, the Ministry of Agriculture deliberately ignored the problems (Frouws, 1994). The White Paper on *Intensive Animal Husbandry* (1974) trivialized manure problems, emphasizing instead the economic successes and technical performance improvements in the bio-industry. When the Ministry of Environmental Affairs became concerned in the mid-1970s, the Agriculture Ministry engaged in trench warfare, arguing that they were responsible for manure and animals (Frouws, 1994). They subsequently blocked all regulations proposed by the Environmental Ministry. The Agricultural Ministry also frustrated attempts at quantitative analysis of manure problems by the independent Central Bureau of Statistics (CBS).[13] Between 1974 and 1982, the Ministry prevented the publication of CBS manure-reports by challenging technical calculations, demanding extreme standards of accuracy, and pointing to uncertainties in calculations (Termeer, 1993). The lack of quantitative CBS-data hindered effective policy making. The CBS-report was finally published in 1984, when stench and water pollution problems were smellable, visible and pressing (Frouws, 1994: 81). The same year, under societal and political pressure, the Agricultural Ministry issued the Interim Law, which set limitations on the expansion of pig and poultry farming. Ironically, the law triggered a wave of expansion, because farmers exploited loopholes in the Interim Law. The number of pigs increased with 28% between 1984 and 1987, when the Manure Law was finally introduced (Frouws, 1994).

3.3. Interpretive: Local learning and changing interpretations

General paradigm
In the interpretive paradigm, which is rooted in micro-sociology (symbolic interactionism, ethnomethodology), actors are perceived as creative and interpretive, using cognitive rules for sensemaking (Weick, 1995). Interpretive rural sociologists, who see farmers as knowledgeable actors, highlight bottom-up dynamics such as local learning by farmers, negotiation, and gradual adjustment of practices (Van der Ploeg and Long, 1994). This approach criticizes agrarian political economy approaches because of its structural and deterministic overtones. With regard to transitions, interpretive scholars emphasize learning processes, interactions, and negotiations through which actors change their interpretations. These changed interpretations subsequently influence the direction of their activities (e.g. policies, investments).

Explaining the bio-industry transition
In the 1950s, incumbent actors, such as the government and NFA's, changed their perception of the 'small farms problem', which traditionally formed the bulk of Dutch agriculture.[14] In the 1930s, when small farms faced economic difficulties, the Ministry and NFA's shared the perception that small farms should be supported (Somers, 1991). Hence, in 1936, the government established the Agency for Small Farms

[13] CBS wanted to collect and analyze quantitative data about the number of pigs, the minerals in their diets, manure production, and use of manure as fertilizer.

[14] Between 1890 and 1910, the number of small farms (< 5 ha) grew from 76.910 to 109.620, and then remained more or less constant until 1950 (Somers, 1991).

(ASF), which provided direct support in the form of fertilizer, animal fodder, certified seed and seed-potatoes. The ASF and extension service provided information about rational practices that would limit farmer's expenses and increase their yields, e.g. more balanced manuring, more rational farm equipment, cheaper input materials and new corn varieties (Somers, 1991). These support measures were linked to the belief that farmers were invaluable to a healthy society (also section 3.5).

After the war, economic and sociological researchers articulated a new problem definition. Through articles in the *Monthly Journal for the Extension Service* they argued that the economic problems of small farms were not only related to the economic Depression, but also to the labour surplus in rural areas (Karel, 2005). They perceived small farms as a *structural* economic problem: agricultural incomes supported too many people, leading to low per capita incomes. The perceived solution was a discharge of the rural labour surplus. The efficiency of small farms should be improved, so that they needed less (hired) workers (Van der Ploeg, 2001).

Between 1949 and 1958, this new problem definition diffused to policy makers and NFA's via three high-profile commissions, which studied the 'small farm problem'. They concluded that labour productivity should be improved through rationalization (which would improve efficiency) and mechanization (which would increase outputs and reduce labour needs).

As interpretations subsequently shifted from the farm-level to the sectoral level, the problem was increasingly defined in terms of economic structure (Van den Brink, 1990). Instead of improving *existing* farms, the new idea was to decrease the number of (small) farms, thus altering the economic structure (Van den Brink, 1990). The perception of small farms changed from ‘problem to be solved’ to ‘problem to be removed’. By 1955, the government concluded that small farms should either improve and enlarge or disappear. The government's Long-Range Plan for Land Consolidation (1958) explicitly articulated the goal of a 50% reduction in the farm population in 20 years time.

This new perception was opposed by the NFA's, which saw themselves as representing the *entire* agricultural population. The NFA’s argued that small mixed farms *could* have an economic future and should not be abandoned (Van den Brink, 1990). The NFA's defended small farms by criticizing AERI’s cost calculations, which formed the basis for yearly negotiations about the level of guaranteed prices (Duffhues, 1996). They argued that calculations should be differentiated to represent *real* costs for different farms, instead of being based on *best-practice* farms.

So, between 1950 and 1960, there were tensions and debates within the corporatist coalition. Meanwhile, rural sociologists, who usually identified with modernization ideals (e.g. Hofstee, Benvenuti), contributed to the debate by investigating cultural patterns and farmers’ lifestyles (Karel, 2005). Their reports concluded that some farmers had a 'modern dynamic cultural pattern' while others were more 'traditional'. These terms had normative and performative implications, legitimating the government's perception that some farmers were inherently more innovative than others. The sociologists also concluded that modernization required farmers to abandon their ‘traditional’ agrarian ethic and adopt an entrepreneurial attitude. Hence, extension services should not only engage in knowledge transfer, but also influence traditions and attitudes (Karel, 2005).

The stream of economic and sociological reports eroded the NFA's attachment to small farms. By 1960, the NFA's accepted the new vision, as indicated by diminishing criticism on cost calculations (Van den Brink, 1990). They also supported the Development and Buy Out Fund (1963), which explicitly stimulated the termination of small farms. New symbolic terms in the policy discourse, such as the distinction between 'stayers and leavers', signalled the acceptance of the new vision. This vision was subsequently implemented with policy instruments (section 3.2).

Interpretive changes also occurred at the farm level, as farmers changed their practices in a gradual and stepwise process. Mixed farming was labor-intensive, with farmers performing a range of diverse tasks. In the mid-1950s, decreasing agricultural prizes and increasing labour costs created economic pressures (section 3.1). In response, some farmers intensified and increased the number of pigs. They constructed additional low-cost sheds against the main building (Crijns, 1998). By 1960, small farmers, who had little hired workers, increasingly recognized the relative inefficiency of too many small operations (Duffhues, 1996). Extension services and NFA's also drew attention to this problem. Although most farms remained mixed, they abandoned some tasks (e.g. poultry farming). They also merged multiple small sheds into larger single stables. But this did not (yet) lead to specialization. The shared perception was that mixed farming was a rational strategy of spreading risks (Termeer, 1993). Specialization and reliance on one product were thought to create vulnerability to price fluctuations, a clear lesson from the Great Depression.

The moderate scale increases created new bottlenecks, e.g. time-consuming manure removal, which still occurred by hand. Hence, farmers gradually adopted mechanical slides, operated by winch and motor power, to shove manure out of the stables (Crijns, 1998). Technology suppliers also offered new stable designs that were tailored to the breeding and nurturing of piglets or to fattening of hogs. Although farmers were hesitant about the required investments, the early 1960s saw a process of differentiation in pig farming, with some farmers specializing in breeding and others in fattening.

These developments were stimulated by extension services, which gradually broadened the scope of their activities. Before 1950, they focused mainly on technical farm *components*. Between 1950 and 1960, they gave more attention to interactions between components and efficient operation at the entire *farm-level* (Crijns, 1998). Extension services also addressed financial and economic issues. Advisers visited farmers at home or gave evening courses to teach them bookkeeping skills and investment calculations (Karel 2005). They aimed at providing farmers with the mental tools to become rational agents. Such mental changes were more explicitly strived for in the 1960s, when extension services took sociological research as their guiding principle and set out to change 'traditional' attitudes and routines (Zuurbier, 1984). Also policy makers and NFA's tried to convince farmers to change from mixed farming to specialization and scale increase. This was not easy, however, because there were strong sentiments that mixed farming was a rational strategy (Crijns, 1998). The transition thus entailed a shift in (perceptions of) rationality and attitudes.

To convince farmers about the benefits of new practices, extension services organized trips to experimental model farms. These farms, which were owned for 50% by the state, materialized the new vision of specialization, rationalization, and mechanization (Karel, 2005). The Ministry also subsidized regional improvement projects, which aimed at stimulating collective and experiential learning (Figure 6). Initial projects subsidized 50% of the costs of new technologies (Karel, 2005: 97); later projects received lower subsidies. The projects also stimulated network building and the articulation of new entrepreneurial attitudes. Local communities themselves were required to take the initiative and submit a 4-year plan (Duffhues, 1996). They were also required to administer the allocation of resources and monitor progress. While extension services provided assistance, the main responsibilities thus rested with local networks, which involved, for instance, farmers, local NFA's, the mayor, the priest, the agricultural schoolteacher. The projects created new dynamics in local communities, who acquired new skills (bookkeeping, investment calculations) and began to exchange experiences and organize meetings, evening courses, and field trips. Regional improvement projects thus stimulated attitude changes (Karel, 2005).

In this context, young farmers were the first to make the shift towards specialized pig farming in the early-1960s (Crijns, 1998). They were susceptible to the incentives and extension activities, because agricultural schools, which had expanded in the post-war period, had taught them new skills and attitudes, such as bookkeeping and agricultural entrepreneurship (Duffhues, 1996: 405). Specialized pig farms first appeared on the sandy soils of Noord-Brabant and Gelderland, where land was relatively infertile and limitedly available (because of many small famers). Intensive animal husbandry, which required little land, thus provided farmer's sons an opportunity to start a business (Crijns, 1998).

Traditionally, farmers were hesitant towards borrowing money, because financial dependence might threaten farm survival if economic conditions worsened. Farmers only invested money, which they had previously saved (Crijns, 1998). Young farmers, who had learned book-keeping and entrepreneurship skills, were less hesitant about investing with borrowed money. Other farmers initially labelled these specialized pig farmer 'gamblers' and 'daredevils' (Termeer, 1993). In the late 1960s, mainstream attitudes and perceptions changed, however, because specialized pig farmers achieved good economic results. Positive external conditions, such as the European Union’s Common Agricultural Policy, governmental support measures, and cheap food imports, also stimulated changes in perceptions.

In the 1970s, other farmers also began to shift from mixed farming to specialized pig farming. Farmers' sons, who had previously left farming for lack of opportunities, returned and bought small plots of land, on which they constructed pig husbandry systems. Feed companies and meat processing industries also moved into the business (see section 3.4), introducing 'contract-farming' as new organizational form, i.e. hiring farmers to fatten pigs for them. This reduced financial risks, but implied that farmers lost their independence and became salaried employees (Crijns, 1998). While farming used to be steeped in tradition, with farmers priding themselves for having a special vocation or mission, it was increasingly seen as a normal job. The moral pressure to keep the farm in the family and pass it on to their children weakened (Schnabel, 2001). Also policy instruments, such as the Buy Out Fund (1963), suggested to farmers that it was not shameful to sell their business.

The concrete enactment of the bio-industry transition thus involved hesitations, doubts, debates, attitude and perception changes, and new roles for different actors.

3.4. Functionalism: Interacting sub-systems and chain analysis

General paradigm

The functionalist paradigm assumes that social systems have certain 'needs' or 'functional requisites'. The role of human actors is to fulfill these needs, remove tensions and ensure system integration. Parsons' structural-functionalism is a prime example. Parsons theory has been criticized for its teleological connotations, its focus on consensus and stability rather than conflict and change, and its 'over-socialized view' of actors, who have little choice but to follow norms and act out functions.

Functionalism also emphasizes the integration of subsystems.[15] When internal sub-system developments lead to strains, actors need to create harmony at the systems level. In rural sociology, this paradigm underlies the food Commodity System Analysis (Friedland, 1984) and food supply chain analysis (Marsden *et al*., 2000). These approaches analyze entire food systems and the actors involved. Transitions arise from tensions, caused by sub-system developments, and subsequent efforts to create new relations that overcome the tensions.

Explaining the bio-industry transition
Some important sub-systems and actors in the pork chain were food suppliers, slaughterhouses, supermarkets, and consumers (Table 1).
* Feed and trading companies, which farmers created in the late 19th century to improve their bargaining positioning in the import of cattle feed and fertilizer, became crucial actors in the bio-industry transition. In the 1920s and 1930s, the trading companies became involved in the *production* of animal feed (Veldman *et al*., 1999). This business exploded in the 1960s and 1970 (Figure 7), as farmers shifted to specialized bio-industry. In 1977, feed sales of *CeBeCo-Handelsraad*, the largest animal feed company, were about 1.2 billion guilders, accounting for 55% of total sales (Veldman *et al*., 1999: 194).[16]

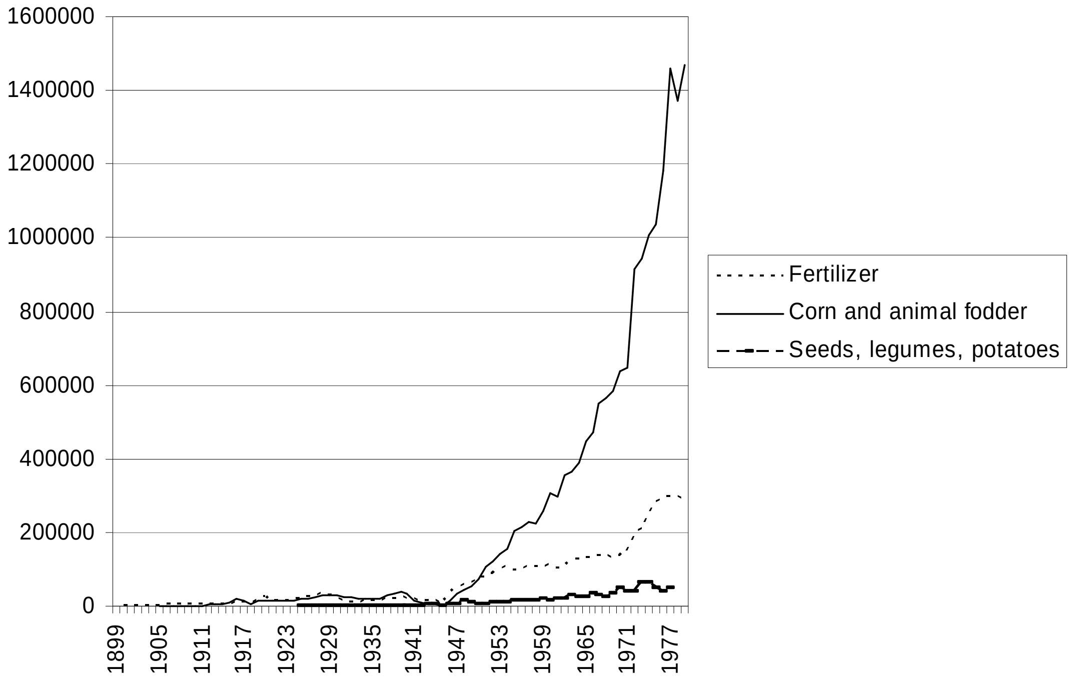

Figure 7: Turnover from CeBeCo-Handelsraad (in thousand guilders) of animal fodder (upper line), fertilizer (dotted middle line) and seeds, legumes and potatoes (bottom line) (Veldman et al., 1999: 94)

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[15] For society as a whole, Parsons distinguished an economic subsystem (adaptation), a political subsystem (goal-orientation), a social subsystem (integration), and a cultural subsystem (latency).

[16] In the post-war period, trading companies also moved into other commercial areas such as stable construction, the import of agricultural machines and the provision of services such as maintenance, repair and technical support (Veldman *et al*., 1999).

To create stability and guaranteed markets for pig feed, which formed their biggest market, trading companies moved into pig farming. In the mid-1960s, *CeBeCo* and feed company *Hendrix* created their own pig farms and engaged in contract farming (Schönwetter, 1999). These contract-farms, which were supported by big agribusiness, were much larger than other farms and set new benchmarks in the process of scale increase. Some of the trading companies also moved into slaughtering and meat processing. *CeBeCo*, for instance, joined the *Meat Cooperative* in 1964, which later merged with the *Saveco-Wellinggroup* to form *Coveco*. *Coveco* operated seven large slaughterhouses and several meat wholesalers, and conquered almost 15% of the market (Veldman *et al*., 1999). Trading companies thus transformed into large agricultural conglomerates that used forward and backward integration to create the predictability and control that were necessary for industrial-scale operations.
* Slaughterhouses and meat processing companies enacted a similar process of scale increase and (backward) integration into pig farming. Following the Meat Inspection Law (1922), which specified strict hygiene standards for slaughtering, many local butchers left slaughtering and moved into retailing. Hence, the number of professional slaughterhouses increased rapidly in the 1920s (Schönwetter, 1999). Home slaughtering, which was still widespread, was exempted from the law. Slaughterhouses gradually diversified into related branches, using animal fat, especially from pigs, for the production of margarine, soap, fats and oil. They also moved into meat processing, producing sausages, liver pâté, hams, bacon, and canned meat. The required investments in machines and buildings formed incentives for mergers and takeovers in the 1940s (Koolmees, 1991). The meat processing industry further expanded in the 1950s and 1960s because of stimulating influences from new retail forms, such as self-service grocery shops and supermarkets, which offered an increasing variety of processed meat products, e.g. pastries, pies, canned and pre-cooked sausages. Multi-national firms, such as *Unilever*, moved into meat processing in the late 1950s and signed contracts with pig and cattle farmers to ensure a reliable supply of meat (Schönwetter, 1999). To ensure high quality, the new Meat Inspection Law (1957) issued tighter hygiene regulations (Koolmees, 1991). Exemptions for home slaughtering were also withdrawn, leading to a rapid decline of this private circuit (Table 7).

	1955	**1960**	**1965**	**1970**
Cows	7.357	5.273	5.454	4.292
Pigs	250.769	150.737	84.860	37.793

Table 7: Number of yearly home slaughtering (Agricultural Economic Research Institute, 1972: 92)

The EU Directive on Fresh Meat (1965), which further tightened hygiene regulations, required slaughterhouses to modernize. They created new disassembly lines, new machines for heavy cutting, new floors and buildings with better cleaning facilities, and new facilities for deep-freezing (Koolmees, 1991). Investments and scale increases led to a new wave of mergers and takeovers. To secure more stability and control over the supply of animals, slaughterhouses and meat processing factories moved into pig farming. They set up their own pig farms (e.g. Homburg in 1963) and used contract farming (Schönwetter, 1999). This backward integration also enabled them to avoid the price fluctuations that characterized livestock markets ('pig cycles'). Slaughterhouses also demanded that the pigs, which were supplied, remained within

narrow margins of particular sizes, shapes, and meat/fat ratios. The slaughtering machines were designed for particular specifications. Slaughterhouses and meat-processing factories thus contributed to the standardization of feeding and breeding practices, which ensured uniform weight and homogeneous quality of pigs (Koolmees, 1991).
* Shifts in retailing, particularly the rise of supermarkets, influenced pig farming by specifying certain demands to slaughterhouses and meat processing factories. Supermarkets, which formed a commercial innovation, increased from 1 in 1954 to 50 in 1961 to 700 in 1967. As they grew in size and number, they created stiff competition for small foodstuff shops, which decreased from 24.000 in 1960 to 11.538 in 1980 (Montijn, 1991). Supermarkets blurred the boundaries between branches, which were previously separated. Previously, the Law on Business Licensing Conditions (1939) specified that grocery stores could operate in a maximum of three product branches and that special certificates were needed for fresh products (meat, milk, fruit, vegetables). This, in effect, protected small bakeries, butchers, and greengrocers. The Law was relaxed in 1954 and 1961, allowing supermarkets to combined dry products and foodstuffs from grocery stores with fresh products from regular markets (hence the term 'supermarket'). Meat was one of the fresh products that supermarkets moved in to, something that required major investments in cooling technologies, supply chains and distribution centres (Sluijter, 2007). This enabled supermarkets to supply fresh meat throughout the year, thus breaking the traditional seasonal cycle in pig farming. To ensure this steady supply, supermarkets signed contracts with slaughterhouses and meat processing factories, who, in turn, integrated backwards into pig farming. The entire pork chain thus became increasingly integrated.
* On the user side, a striking change was the doubling of pork consumption between 1950 and 1980 (Figure 2). This increase was related to declining relative meat prices and increasing wages (Figure 4). While the relative share of meat in food expenditures increased, the share of food in total family expenditures went down, from about 50% in 1949 to 22% in 1979 (Figure 8).

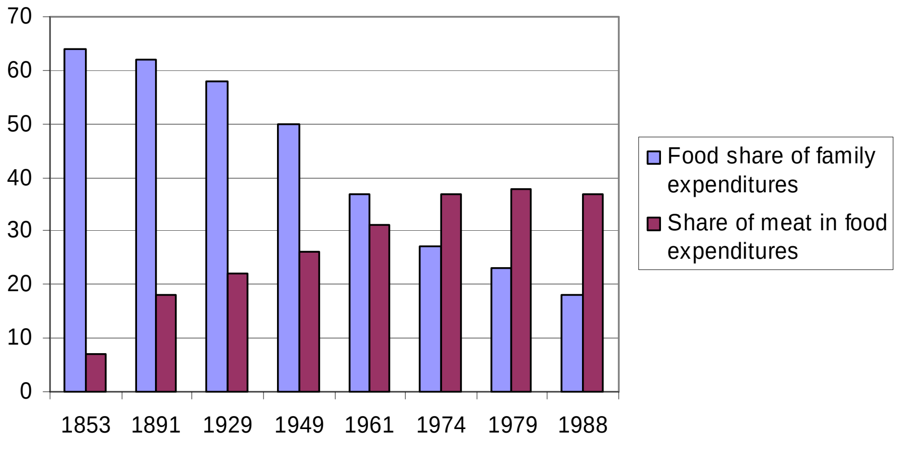

Figure 8: Relative share (%) of food within family expenditures, and share of meat (%) within food expenditures (Scholliers, 1993: 135)

Another change was a shift in consumer preference from fat meat (bacon, lard) to lean meat (pork chops, hams). Especially factory workers and farmers, who did hard physical labour, traditionally appreciated fat meat because of its high energy content

(Jobse-Van Putten, 1995). After the war, the number of office jobs increased and the daily caloric needs diminished. The emergence of new beauty norms, which placed more emphasis on being slim and slender, also influenced the changing user preferences.

Another change was from preserved meat to fresh meat. In the early 20th century, many animals were slaughtered at home and preserved through curing, salting, vacuum preservation in glass bottles. During winter and early spring, many people relied on this preserved meat. In the post-war period, refrigerators rapidly diffused, from 2% of households in 1947 to 40% in 1964 and 86% in 1985 (Van Otterloo, 1990: 175). Refrigerators facilitated a shift towards year-round fresh meat. The traditional seasonal dependence was broken, because of the creation of a complete 'cold chain' of deep freezers and refrigerators (from slaughterhouse to supermarket to consumer). The diffusion of the refrigerator also influenced shopping patterns and the rise of supermarkets. It became possible to buy food products once a week and preserve fresh products in refrigerators or freezers (Montijn, 1991).

The place of meat within the meal also changed. The pre-war preservation methods were imperfect, and the quality of meat deteriorated gradually. This deterioration was hidden by serving meat in one-pan dishes (e.g. stews, hotchpotch), where other ingredient could improve the flavour (Jobse-Van Putten, 1995). For working class families, these one-pan dishes were also common, because fire or coal-heated stoves were difficult to regulate. Between 1900 and 1940, a gradual transition occurred from these one-pan dishes, where meat did not have a separate place in the meal, towards the 'standard Dutch meal', consisting of two bread meals and one hot meal in the evening (Scholliers, 1993). This hot meal consisted of three separate dishes: potatoes, vegetables and meat, which was valued most (Van Otterloo, 1990). These changing food practices prepared the ground for the post-war expansion of meat consumption.

* In sum, the importance of other sub-systems besides farming increased during the bio-industry transition. In 1950, primary pig farming earned about 60% of total income in the pork chain (Douw, 1990: 50). In 1980, farmers earned 19%, commercial food manufacturers 18%, meat processors 29%, trade, transport and services 27%, and other non-agricultural companies 7% (Termeer, 1993: 54). As food chains expanded, pig farming was increasingly susceptive to dynamics in other sub-systems.

3.5. Structuralism: Cultural traditions, ideology, and discourse

General paradigm

The structuralist paradigm perceives actors as embedded in cultural 'deep structures', e.g. ideology, traditions, symbolic sets. Structural anthropologists (e.g. Lévi-Strauss) used this paradigm to interpret foreign tribes. Philosophers of technology (e.g. Heidegger, Ellul, Habermas) applied this kind of analysis to western societies, analyzing cultural assumptions that provide positive contexts for industrialization and modern technology. Their 'massive' view of culture, which operates 'behind the backs' of actors, leaves little room for agency and change. Recent cultural sociology focuses more on dynamics interactions between actors and culture. In their struggles over legitimacy, actors use cultural symbols and repertoires in a more strategic way (Swidler, 1986). With regard to transitions, structuralist scholars highlight the importance of changing traditions, cultural framing and ideology.

Explaining the bio-industry transition
Agricultural literature in this tradition situates aspects of the bio-industry transitions in broader and longer-term contexts.
a) Socio-political culture of the 1950s and 1960s. The post-war decades had several characteristics that enabled policy makers, experts and NFAs to influence the bio-industry transition. One characteristic was technocracy, the belief that science and technology formed the rational basis for the improvement of society. This belief explains why engineers, economists and sociological experts had so much influence. Agricultural policy relied strongly on the economic analyses and models provided by AERI, which functioned as agricultural planning bureau (Van der Ploeg, 2001). Rural sociologists influenced policy-making by providing cultural categories that legitimized modernization. Actors who opposed the proposed modernization process or had different views, were labelled 'backward', 'traditional' and 'non-rational', requiring them to be 'educated' through a dynamic 'cultural offensive' that aimed at changing their mentality (Karel, 2005).

Actors also shared the belief that the state should play an important role in restructuring society. A discourse of rational planning and modernization accompanied the rapid expansion of the state apparatus (policy makers, extension services, public research). Agricultural policy makers and experts saw America as guiding nation, because of its advanced position in agricultural modernization, mechanization and large-scale production. This exemplar and the new discourse help explain why policy makers changed their interpretation of small farms (section 3.3).

The 1950s and 1960s were also characterized by public respect for authorities, providing them with a societal mandate to guide the nation. such as politicians, mayors, and schoolteachers. This trust in policy makers, academic experts, and representatives from farmers associations explains why protests against agricultural modernization were relatively mild. It also explains why extension, education and information activities were often used as policy instruments.
b) Beliefs about the societal significance of farmers. Before the war, farmers were perceived as moral backbone of society, invaluable to a healthy society. They were presumed to have specific rural virtues such as attachment to the land, solidarity, indifference to the whims of urban culture, common sense, hard work, and thrift (De Haan, 1993). This ideology explains why small farms were supported when they faced difficulties.

These cultural beliefs changed after the Second World War, when agriculture came to be seen as a normal economic sector that should contribute to the economy at large (De Haan, 1993). These changes were partly related to broad political changes such as the prominence of Social Democrats in post-war coalition Cabinets (until 1959). The social democrats adopted a moderately liberal ideology: they assisted entrepreneurs if their business was viable; otherwise, they should disappear (Nooij, 1993). The ideology about the moral importance of farmers was replaced with new ideals centred around rational, entrepreneurial farmers.

> "Several cultural myths were pressed into service in the early 1960s to establish and defend agricultural policy. (...) This vision played down the role of the family and elevated the person of the farm operator to the level of a rational entrepreneur. Thus arose the spectre of an autonomous, self-employed farmer, detached from family influences and sentiments, motivated by profit maximization and an industrial lifestyle" (De Haan, 1993: 155).

This new ideology provided cultural legitimization for policy measures that stimulated the bio-industry transition. These cultural changes, to which rural sociologists contributed, also explain why small farmers and deep-rooted agricultural values came to be seen as problematic in the 1950s and 1960s.

c) Food culture. Ideas about cooking and meals changed over time, and were influenced by an intermediate field:

> "In the 1920-1960 period, the food chain was enriched with new actor groups and organizations, striving at advancing and modernizing eating and living. Educational organizations and advice institutions began to shape a *new intermediate field* between production and consumption, focused at attuning both ends of the chain. (...) During this period optimistic ideals to improve the *quality* of food, cooking, housing and living were shared by industrial food companies, local and national government authorities, new educational institutions and groups of scientists. Cookery schoolteachers and other women's organizations, for instance, were active in diffusing 'modern, rational' knowledge on food quality, choice and preparation. The American dream of the good life shimmered already in the periods between the wars". (Van Otterloo, 2005: 262-263).

Domestic science schools, for instance, which prepared girls for a later 'career' as housewife, taught them how to cook tasty, nutritious meals with little money. In the late 1930s, about seventy thousand girls between thirteen and fifteen years old attended these schools (Montijn, 1991: 123). Values such as sobriety, hygiene, thriftiness, and convenience thus became part of the Dutch food culture.

In the 1930s and 1940s, intermediate field actors also conveyed the idea that the meal was a crucial meeting place for the family (Scholliers, 1993). In the middle-class ideology, which experienced its heyday between 1920 and 1970, women could achieve status and appreciation as 'kitchen princess'. As food and meals became expressions of care and nurturing, the interest in cookbooks, magazine recipes, and culinary advertisements grew (Montijn, 1991). These cookbooks emphasized the preparation of separate dishes, paying special attention to meat (Segers, 2005). Cookbooks and women's magazines thus reinforced the cultural significance of meat, even before most families could buy it on a daily basis (Scholliers, 1993).

Although recipes and cookbooks highlighted increased sophistication of meals, other values such as low cost, nutritional value, and convenience, remained at least as important. The Netherlands is characterized by an instrumental food culture, which values low prices more than high quality (Table 8).

Instrumental: eat to live	**Quality: live to eat**	**Joy: Mediterranean kitchen**
North-West Europe (Britain, Netherlands, Ireland, North-Belgium)	Central Europe (France, Germany, Denmark, South-Belgium, Luxembourg)	Southern Europe (Portugal, Spain, Italy, Greece)
Price-sensitive	Quality-sensitive	Pleasure motive
Quality less important	Price less important	Fresh products
Food is necessary, not pleasure	Food is social event	Food is social event
Many processed foods	Both processed and unprocessed foodstuffs	Mainly unprocessed foodstuffs
Fast and convenient	Traditional	Very traditional

Table 8: Different (European) food cultures (Jobse-Van Putten, 1995: 529)

This low-cost focus of Dutch food culture provides an additional explanation for the mass production adopted by Dutch pig farmers. Although flexible specialization was an alternative, the low-cost bulk strategy was more in line with Dutch food culture, and therefore more likely than the high quality/high cost strategy.

4. Analysis and conclusions

Foundational paradigms thus provide different explanations of the bio-industry transition, highlighting different processes and mechanisms. Each explanation is internally consistent with its foundational assumptions. Hence, there is not *one* best explanation. Nevertheless, single-paradigm explanations are limited and reductionistic, emphasizing some causal mechanisms at the expense of others. For more encompassing explanations, multi-paradigm analysis is promising (Gioia and Pitre, 1990; Lewis and Grimes, 1999). But different explanations cannot simply be added up, because of major differences in ontological assumptions. Although complete integration is not possible, the analysis below identifies crossovers and complementarities between different paradigms as well as strengths and weaknesses.

Rational choice

The strength of the rational choice explanation is the identification of economic benefits that front-runners in the bio-industry transition experienced. The analysis of factor costs, prices, investments and incomes identifies important micro-motivations for farmers. Weaknesses are related to some of the ontological assumptions. One assumption is that farmers are rational entrepreneurs who make cost-benefit calculations. As the interpretive paradigm showed, this rationality did not automatically exist, but was actively created. Extension agencies, representatives from farmer associations and agricultural schools educated farmers to become rational agents, teaching them new methods and tools such as bookkeeping and accounting. Also through projects and home visits, they tried to changing farmers' attitudes about entrepreneurship, borrowing money, etc. The interpretive paradigm thus complements rational choice, making the assumption of rationality into an analytical topic.

Teaching farmers to become rational agents weakened the influence of macro-actors (such as NFA's and Ministry of Agriculture), which was strong in the 1950s and 1960s as farmers respected and trusted them. When farmers developed into rational entrepreneurs, they became less compliant to top-down plans and more self-interested. Farmers' opportunistic reaction to the loopholes in manure Interim Law (1984) is an example. This eroding influence from collective actors indicates a negative complementarity between rational choice and political economy explanations.

Rational choice also assumes the free availability of information. But the institutional analysis (section 3.2) showed that the collection, creation and dissemination of relevant information depended on the active creation of dedicated organizations (e.g. the Agricultural Economics Research Institute), radio bulletins, and trade journals. Information availability thus depended on an underlying organizational network.

While the rational choice paradigm assumes that rational agents adopt the best available technology, it does not explain the *emergence* of new technology. Technical change remains an exogenous variable or is assumed to arise from science (linear model of innovation).

Power (political economy)

The strength of the power and political economy paradigm is that it analyses the formal institutions and incentive structures that frame the agricultural economy. By highlighting the choices, struggles and negotiations amongst powerful macro-actors, it shows that agricultural modernization was not only a market-driven process.

Regulations, subsidies, and structural adjustment programs influenced both production factors and market selection processes.

A weakness is that political economy is a structural approach that downplays agency. More precisely, it highlights the agency of collective macro-actors, but ignores local farmers, who are assumed to be obedient, reacting only to directives and plans from above. It shares this relative neglect of farmers' agency with the rational choice paradigm, which perceives farmers as reacting only to prices. The interpretive paradigm provides a rival explanation that delves deeper into farmer's practices and local agency. On the other hand, Dutch farmers *were* relatively docile in the 1950s and 1960s, trusting and following collective macro-actors. Because this faith was related to broader political-cultural developments (technocracy, ideology of strong state influence, modernization discourse), there is complementarity between the political economy and structuralist paradigm.

A second weakness is that the political economy paradigm says little about the specific *content* of the bio-industry transition. It analyzes the broad process of agricultural modernization, not the specific dynamics of pig farming. It shares this neglect with the rational choice paradigm. Both paradigms explain the speed of change, but say little about its precise content and form. This is related to the conceptualisation of technological change, which in both cases is close to the linear model. New technology arises from R&D and subsequently disseminates via the market or extension services, which act as intermediary to farmers (the ERE-triptych). This one-way flow model fails to see the 'return-flow' with farmers articulating their experiences and the kinds of problems they face (user-producer interactions).

Third, rational choice and political economy both have a productionist bias, emphasizing factors that influence the production side, but neglecting households, consumers and cultural aspects. The reason is that both paradigms acknowledge the centrality of the market. The difference is that political economy argues that markets are framed by formal regulations, incentives, plans etc. Both paradigms thus complement each other.

Fourth, the political economy paradigm focuses on the implementation of the modernization vision through different instruments and incentives, but leaves the *origins* of this vision under-addressed. The interpretive paradigm provides a complementary analysis, showing that the new vision emerged from a change in discourse and problem framing (especially of small farms).

Interpretivism

The strength of the interpretive analysis is the undermining of linear explanations that emphasize the automatic character of the transition. With regard to collective macro-actors, the interpretive analysis showed that problem definitions of small farms and perceived solutions changed between 1945 and 1960. It thus situates the roots of the transition earlier than the other two paradigms. The interpretive analysis also showed that the new modernization vision was initially contested by farmer's association. Consensus in the corporatist coalition did not exist automatically, but was actively constructed. Some actors proposed alternative modernization visions, e.g. high-priced specialty production and intensification (do more with small plots). This alternative, which would have protected small farms, might have worked if other instruments had been chosen to stimulate the emergence of flexible innovation networks.[17] Instead, powerful macro-actors chose to support the mass production pathway. This particular modernization path had no intrinsic necessity, but emerged from choices by powerful actors (Van der Ploeg, 2001).

With regard to local farm practices, the interpretive analysis showed that the transition towards bio-industry occurred as stepwise process with hesitations, doubts, struggles, debates, learning processes, and changing perceptions. Sequences of experimental and demonstration projects played an especially important role in this process, enabling learning trajectories that assisted local transformation processes and the creation of community-based innovation networks. Learning processes not only addressed technical practices, but also mental attitudes, entrepreneurship and accounting skills. This paradigm also highlights the interactive dimension of technological change, with farmers talking back to extension services and researchers. Local transformations thus appear as multi-actor processes with technical, cultural and social dimensions.

Interpretive explanations complement the political economy analysis. On the one hand, broad general visions, as emphasised in the latter, provide general directions for learning processes. On the other hand, concrete implementation proceeds through local enactment and projects that involve interpretations, adjustments and negotiations of specific details. The enactment of a new vision inevitably involves learning processes to acquire new routines and practices.

A weakness of the interpretive paradigm is that it gives little attention to broader institutional structures and economic processes. The analysis assumes much freedom of local agency, suggesting that 'things could have been different'. Other paradigms provide useful antidotes here. The rational choice analysis showed that declining prices and incomes formed powerful incentives for change in certain directions. In principle, flexible specialization was an alternative to mass production. But the modernization vision was more powerful because it linked up with broader political and cultural trends (e.g. changing views on the moral significance of small farmers, the Dutch food culture that emphasized low costs instead of high quality). In this broader context, the mass production path was more likely than the alternative. Political economy, rational choice and structuralist paradigms thus provide useful antidotes against assumptions of too much 'free' agency in local interpretivist explanations.

Functionalism (systems analysis)

The strength of functional analysis is that it widens the scope of analysis beyond the farm gate, and incorporates dynamics in other sub-systems. The case study supports the assessment that food systems in the 20th century experienced three generic processes: lengthening, differentiation and condensing of chains (Van Otterloo, 2005. The pork chain ‘lengthened’ because the number of links and geographical distances increased; both the import of pig feed and the export of pork became more international. The system ‘differentiated’ because the networks within the sub-systems became more complex (e.g. pig farming differentiated in breeding and fattening, slaughterhouses specialized in different animals, meat processing factories specialized in different products). The system also ‘condensed’ because different sub-

[17] Alternative instruments, such as direct subsidies, were in fact proposed by contemporaries such as a study committee of the Agricultural Board in 1957, and the influential Social-Economic Council in 1959 (De Groot and Bauwens, 1990: 149).

systems were increasingly aligned, both through forward and backward integration and the emergence of new groups (*intermediate field*) who aimed at attuning production and consumption.

A weakness is that the analysis of linkages and interactions between the sub-systems focuses predominantly on material flows and economic interests, giving less attention to changing interpretations and power struggles. More attention could also be given to the role of intermediary actors in sub-system linkages (in analogy with the intermediate field analysis).

Structuralism (cultural discourse)
The strength of structuralist and cultural analyses is that they provide a macro-view, which situates the bio-industry transition in broader contexts. It does not provide integral explanations, however, but complements explanations in other paradigms. It complements the political economy explanation by analysing the broader political culture which enhanced the influence of authorities in the 1950s and 1960s. The analysis of Dutch food cultures and changing ideas about the societal significance of farmers helps explain the choice for a strategy of low-cost, large-scale modernization instead of high-quality flexible specialization. This complements the rational choice and interpretive explanations. The structuralist paradigm complements the functional analysis with regard to consumption and user preferences. While the functional analysis demonstrated *that* consumption practices changed, the structuralist analysis also explains *why* user preferences changed and were embedded in long-term processes (the role of intermediate field actors and discourses about middle class ideology, changing roles of the meal in family life, growing importance of meat as separate dish).

The danger is that structuralist explanations operate 'behind the backs' of actors, pay little attention to agency and tend towards cultural determinism. This problem is alleviated when structuralist explanations are complemented with other types of explanations. Cultural deep structures then form a context on which actors can draw, e.g. to provide legitimacy for political programs or make certain interpretations more or less plausible.

The conclusion is that paradigmatic explanations are not completely incommensurable. Specific crossovers and complementarities do exist and point to richer explanations. This kind of multi-paradigm analysis is important for sociotechnical transitions, which involve many types of actors and processes. In principle, all social groups can be analysed from each ontology. It is perfectly possible to make a structuralist discourse analysis of butchers or supermarkets, or a rational choice analysis of consumers. The literature, however, does not make such a symmetric analysis. Agricultural and food history tend to link particular ontologies to certain groups, e.g. rational choice to farmers, power to policy makers and farmer's associations (see Table 9). This explains asymmetries in the bio-industry explanations in section 3.

	Farmers	**Policy makers**	**Farmer's associations**	**Consumers**	**Suppliers**	**Butchers, supermarkets**
Rational choice	X					
Power		X	X			
Interpretivism	X	X	X			

Functionalism	X			X	X	X
Structuralism	X	X		X		

Table 9: Main linkages between social groups and paradigms in the present literature on the bio-industry transition

The explanations were also asymmetric in a temporal sense, i.e. the period they considered to be crucial. Structuralism and interpretivism both highlight early periods: changes in interpretations and ideologies in the 1950s, sometimes with roots into the first half of the 20th century. The power paradigm highlights the late 1950s and early 1960s (new vision and subsequent implementation). Functionalism highlights the 1960s (with forward and backward integration into pig farming). And the rational choice paradigm places the main changes in the mid-1960s and further. This suggests that the relative importance of paradigms may vary over time. Economic sociologists further suggest that rational choice and calculation are a special case that is possible when previous articulation processes have produced stable ('cold') cognitive frames and predictable contexts.[18]

How does multi-paradigm analysis relate to the multi-level perspective on transitions (Geels, 2002)? In a previous article, Geels and Schot (2007) used Poole and Van de Ven’s distinction between local and global models, which should complement each other in developmental theories. We characterized the MLP as a *global* model that maps the entire transition process. This article explored *local* models of transitions, dealing with different conceptions of agency and causal mechanisms. The next step is a stronger theoretical integration of local models in the global MLP. As indicated, we perceive a combination of evolutionary economics, interpretivism (especially in the form of structuration theory) and neo-institutional theory as promising (Geels and Schot, 2007). Theoretical elaboration of this combination is a topic for future work.

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[18] "In 'hot' situations, everything becomes controversial. (...) In 'cold' situations, on the other hand, (...) the possible world states are already known or easy to identify: calculated decisions can be taken." (Callon, 1998: 261).

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4. Anchorage of Innovations: Assessing Dutch efforts to use the greenhouse effect as an energy source

Boelie Elzen, Cees Leeuwis, and Barbara van Mierlo

Abstract
To analyse and understand transitions and system innovations various scholars use the so-called 'multi-level perspective' (MLP). The two key levels in the MLP are the 'socio-technical regime' (an existing system) and 'technological niches' (a breeding ground for alternatives to the system). The interactions between niche and regime, however, are not well understood. We need what Smith (2007) calls a 'theory of linking'. Building on Loeber (2003) we use the concept of 'anchorage' to analyse this interaction. Our case study concerns the Dutch glasshouse horticulture sector which is responsible for 10% of the country's natural gas consumption. Various developments resulted in internal as well as external pressures to bring this down. This has led to a variety of 'alternative energy approaches' for the sector, some internal, some seeking to create new links with other sectors which makes this case very suited to study processes of anchorage. We conclude that the concept of anchorage provides a useful tool to study the interaction between niche and regime and the crooked pathways of 'innovation in the making'. It appears that what we call 'hybrid actors' and 'hybrid forums' play a crucial role in bringing about forms of anchorage. Furthermore, we show that within an ongoing process it is difficult to distinguish between developments leading to 'incremental' innovation and those having a potential of contributing to 'radical' or system innovation.

Keywords: System innovation, Anchorage, Glasshouse horticulture, Energy transition, CO_2 reduction

1. Introduction

The 'multi-level perspective' (MLP) has become an important analytical tool for understanding processes of transition and system innovation (e.g. Geels, 2002 and 2005; Berkhout et al., 2004, Geels and Schot, 2007). The perspective suggests that radical innovation emerges from complex interactions between processes occurring at three levels: socio-technical regimes (the meso level), technological niches (the micro-level) and socio-technical landscapes (the macro-level). This perspective has been used effectively by innovation scholars to analyse historical processes of radical change. Given the time frame considered, such descriptions and analyses necessarily abstract from the messy dynamics that occur within and between projects and networks of actors that are involved in innovation processes. As a result the processes through which practices at niche level interact with those at regime level and gradually shift dynamics in the direction of system innovation are not well understood. (Smith, 2007)

In this article we set out to increase our understanding of such interactions by analysing an ongoing process of change in glasshouse horticulture that has recently picked up speed and has become recognized as an example of 'system innovation in the making'. First, we point to the need of having a better analytical framework for looking at linkages between niche and regime dynamics, and suggest that it is useful to think of the multi-level perspective in a less hierarchical manner. Building on Loeber (2003) we propose the term 'anchorage' as a useful analytical notion in this regard and distinguish between various aspects of it. Subsequently, we identify episodes of anchorage at the interface between niche and regime in the case-study which centres around efforts to transform glasshouse horticulture into an energy supplying sector instead of a major energy consumer.

We conclude that our perspective on anchorage yields meaningful insights in the interaction between niche and regime and the capricious pathways of ongoing system innovations. Our analysis of the case-study shows that what we call 'hybrid actors' and 'hybrid forums' play a crucial role in bringing about forms of anchorage. Moreover, we demonstrate that within an ongoing process it is difficult to distinguish between developments leading to 'incremental' innovation and those having a potential of contributing to 'radical' or system innovation, which has sobering implications for those aiming to support transition and system innovation processes.

2. Enriching the multi-level perspective on system innovation

2.1. The System Innovation challenge

Modern societies face structural problems in several sectors. Animal farming, for instance, suffers from manure problems, ammonia emissions and diseases like BSE and Foot & Mouth Disease. In the energy sector there are problems related to oil dependency, reliability, and CO_2 and NO_x emissions. The transport system suffers from problems like congestion, air pollution (particulates, NO_x), energy use and CO_2 emissions. These problems are deeply rooted in societal structures and activities.

In the past two decades much effort has put in solving such problems with product innovations. Cleaner products and environmental technologies have been developed and end-of-pipe solutions have been introduced. Sometimes these product innovations have led to substantial improvements in environmental efficiency (e.g. automobile catalysts which greatly reduced tailpipe-emissions of pollutants). The focus of these efforts was on the technological artefact.

According to a Dutch study substantial improvements in environmental efficiency (factor 2 as a general average) may still be possible with incremental innovation. (Weterings et al, 1997) But larger jumps in environmental efficiency (possibly a factor 10) may be possible with system innovations. The promise of transitions to sustainability via system innovations is schematically represented in Figure 1. Such system innovations not only involve new technologies, but also new markets, user practices, regulation, infrastructures and cultural meanings.

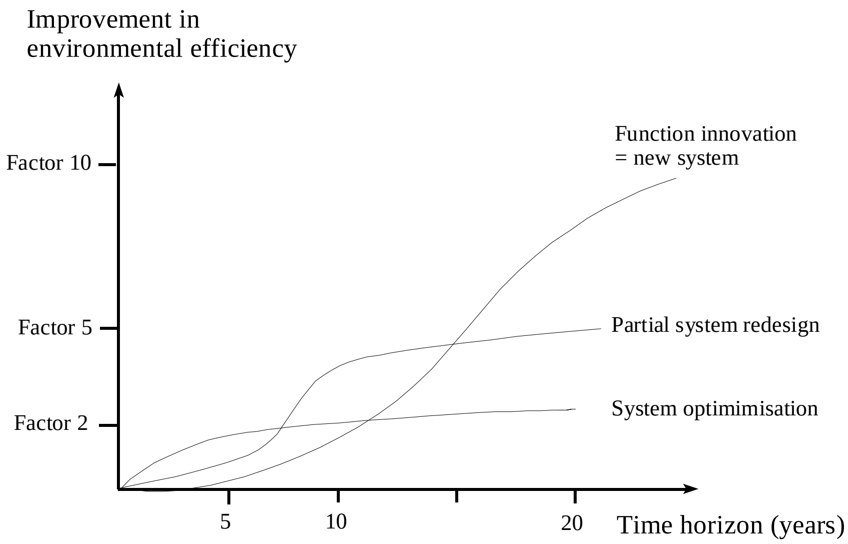

Figure 1. System optimisation versus system innovation (Weterings et al, 1997)

Because of its sustainability promise there is increasing interest from policy makers, NGO's and large firms in transitions and system innovations (see e.g. American National Research Council, 1999; VROM, 2001; Raskin et al. 2002). Also the academic interest in system innovations and developing strategies to induce them within a sustainability framework has grown rapidly over the past few years. A variety of scholars is working on these issues which has lead to a growing body of edited volumes, journal articles and Books. (e.g. Rotmans, 2003; Elzen et al., 2004 and 2005; Olsthoorn and Wieczorek, 2006; Loorbach, 2007; Loorbach et al., 2007)

2.2 The multi-level perspective for understanding System Innovation

To analyse and understand transitions and system innovations various scholars use the so-called 'multi-level perspective' (MLP). This perspective distinguishes three levels (Kemp, 1994; Schot, Hoogma and Elzen, 1994; Kemp, Rip and Schot, 2001; Geels, 2005):

1. The meso level of 'socio-technical regimes' (S-T regimes) which denotes an existing socio-technical system that is embedded in society and links together a wide variety of societal actors (e.g. companies, public authorities, users/consumers). Regimes change continuously but the change, technical as well as societal or behavioural, is of an incremental nature, building further upon an existing socio-technical configuration.
2. The micro-level of 'technological niches'. This denotes protected spaces in which radical innovations are developed. Niches are important as a learning space on issues like technology, user-preferences and -practices, regulation, etc.
3. The macro-level of 'socio-technical landscape'. This denotes the 'external environment' and consists of factors that not only affect the regime under analysis but a variety of other regimes as well.

The relation between the three concepts can be understood as a nested hierarchy, which implies that regimes are embedded within landscapes and niches within regimes. (Figure 2) The linkages between the elements of existing socio-technical regimes provide them with stability, and make it hard for niche developments to be taken up within the regime. However, under specific circumstances, e.g. landscape pressures that make a regime loose its coherence, these novelties may link up to the regime and become a (small) part of it, e.g. in de form of market niches. From there the share of these novelties may start to grow and gradually transform the regime, a process that may include the development of new infrastructures, new institutions and rules, etc. The end result over several decades may be a system innovation.

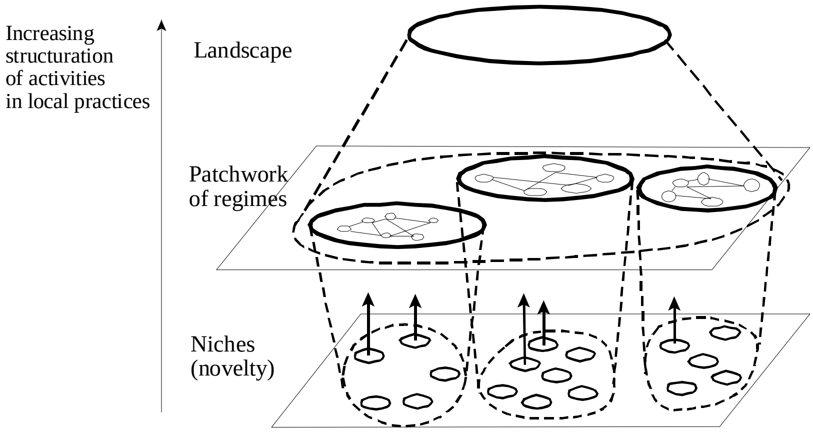

Figure 2. Multiple levels as a nested hierarchy (Geels, 2002)

2.3. Towards a theory of linking

The multi-level perspective has been convincingly used to describe, reconstruct and analyse historical processes of system innovation (E.g. Geels, 2002, 2006). Moreover, it has inspired practitioners to initiate and work on niche experiments. The challenge for them is to develop novelties and learn on how they can be made to work in practice by involving ‘real life’ stakeholders in pilot and demonstration projects. How to do this systematically is elaborated by the approach of ‘Strategic Niche Management’ (SNM). (Kemp et al., 1998, Hoogma et al., 2002, 2005, Van Mierlo 2002) In historical studies, details of the interaction between niche and regime dynamics remain under-exposed due to the long time horizon under consideration, whilst in practical experiments the interaction with the regime is an everyday reality, which however is not usually analysed and theorised. Smith hit the nail right on the head when he wrote in a recent publication (2007, p.431):

> “… the precise relations between niche and regime still requires further analytical attention. Niche practices link up with regimes under stress, resolve bottlenecks and lead to reconfigurations. … However, linkage is understood in the literature to be ‘haphazard and coincidental’. [references to Geels, 2002: p. 29; Schot, 1998] We still do not have a theory of ‘linking’.”

Smith himself made an attempt at filling this theoretical void. One of his starting points is that he sees linking as a two-way influential process. MLP studies typically focus on how a niche influences a system (not out of principle but because of analytical choice). Smith stresses that the influence of regime on a niche is equally important to understand linking. Bos and Grin also stress the importance of analysing how “the regime talks back”. (2008, p. 484) Smith argues further and demonstrates that linking rarely means that elements from a niche are simply adopted but that some form of translation takes place to make this possible. His main argument is that “a focus upon the translation of socio-technical practices between niche and regime will further help theory development. In addition to identifying opportunities for niche-regime connections, we need to understand the connecting processes how these reconfigure developments in niche and regime." (Smith 2007, p. 431; emphasis in original)

Thus, linking is an active process (involving translation) and not a matter of simply adopting elements from a niche in a regime or vice versa. This may then blur the distinction between niche and regime which has implications for the MLP model. To quote Smith (2007, p.447):

> "Whilst this multi-level model has heuristic value, in practice niche-regime distinctions are rarely so clear cut. Distinctions soon break down, as socio-technical elements, but not entire alternative practices, translate from niches into regimes and components of each appear in the other. (…) Without rejecting the multi-level model, the findings here do stress the need for closer attention to relations and translations between levels."

We agree with Smith's conclusions. Moreover, in line with Giddens' (1984) ideas about structuration, we suggest that, at a certain level (e.g. the niche level), influences from other levels (e.g the regime and/or the landscape level) do not somehow operate 'behind the back' of people, but in one way ore another must be brought into the interaction by active human agents who represent (or give representations of) what happens and/or is relevant in other spheres, and translate this into action. (see also Knorr-Cetina, 1988) Thus, different levels and spheres can be distinguished analytically, but from the perspective of interacting agents it may not always be evident whether they operate in the niche, the regime or in both. In order to do justice to this, we propose a new representation of the multilevel model that satisfies the following demands:

- niches and regime overlap to some extent;
- landscape pressures affect niche as well as regime;
- niches, regimes and landscapes are not hierarchically ordered;
- leave intact the overall multilevel heuristic idea.

The result is depicted in Figure 3 which provides an alternative sketch of a multi-level configuration, indicating how the three 'levels'[19] may influence each other in various ways.

[19] Since we present a less hierarchical version of the model the term 'level' seems less appropriate but we continue using the term to be able to relate our work more easily to the existing literature.

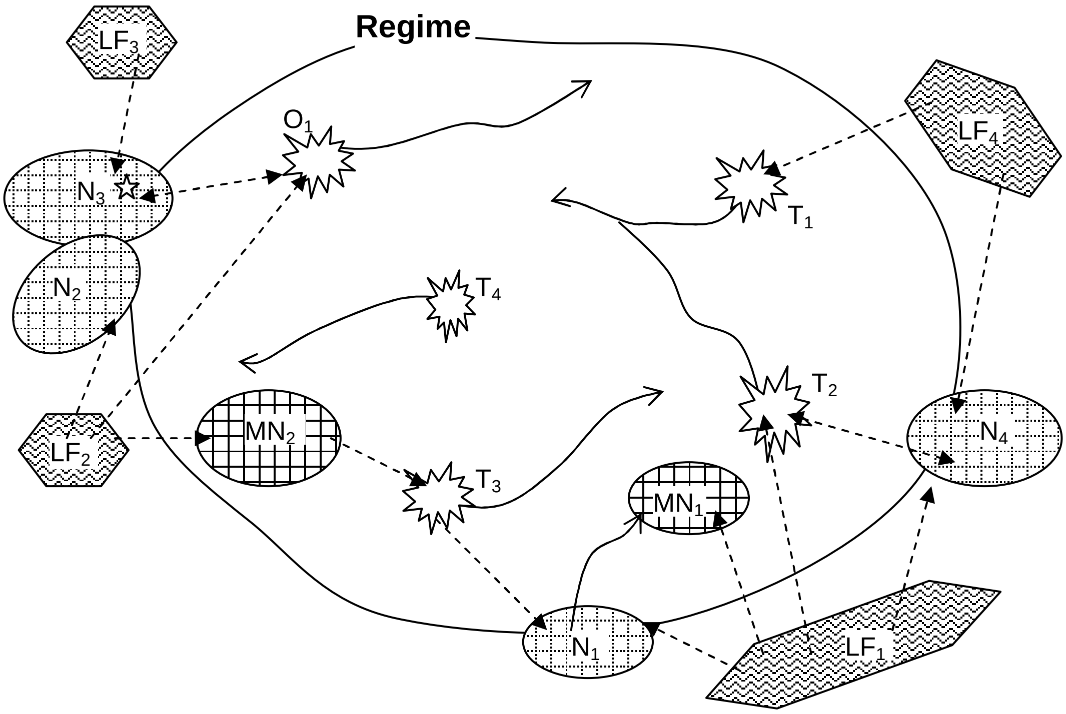

Figure 3: Multi-level processes in system innovation.

In figure 3, the area within the drawn line represents the incumbent regime. At the edges of the regime, several niches are indicated by the small ovals N_1 - N_4. They typically have a partial overlap with the regime (e.g. by using shared technical elements or through actors that operate in the regime as well as in a niche). Some niches may have a partial overlap with each other (e.g. N_2 and N_3). A niche may also transform into a market niche (MN_1, MN_2) meaning that it can survive as a subsection of the regime without protection.

Various landscape factors are indicated by the hexagons LF_1 – LF_4. Although they are all hexagons they have different shapes to indicate they can be varied in nature. Landscape factors are ‘floating all around’ (suggested by the wave-like shading) and may influence the regime, various niches or the linking process between niches and regimes. Niches and the regime may also influence each other as indicated by various dashed arrows.

As is represented by multi-pointed stars (T_1 – T_3), landscape influences and developments in niches may create tensions or opportunities (O_1) in the regime. Tensions can also emerge internally within the regime (T_4), or in niches (see the small star in N_3). From the tensions and opportunities new developments start as is indicated by the bended arrows. The bended shape indicates that the developments are not straightforward although there is a sense of direction due to path dependencies, at least in the short term. Some developments may ‘link up’, e.g. the developments emerging out of T_1 and T_2 in the figure.

With this figure the process of linking refers to what happens at the area of overlap between a niche and a regime. We see linking as a micro-level process that initially leads to small changes that may be more or less durable. Because of our interest in system innovation we are especially interested in those links that are sufficiently permanent to start off development in a direction different from the existing dynamic in the regime and may eventually lead to major changes at the macro level.

We will use the term *anchorage*[20] (Loeber, 2003, Grin and Van Staveren, 2007) to express such forms of linking. Anchorage is related to terms like ‘institutional’ or ‘societal’ ‘embedding’ which are used in literature on Strategic Niche Management (e.g. Hoogma *et al.*, 2002). However, we use the term anchorage to express that a new link has some durability but that the link can also be broken again. Thus, anchorage is more vulnerable and can be seen as a kind of pre-stage that may or may not lead to wider change.

2.4. Exploring anchorage

Before using anchorage to analyse interaction between niche and regime dynamics in the context of system innovation, it is helpful to first develop some sensitising notions on possible forms of anchorage. We will do so by taking Geels’ (2004, pp. 902-903) three general dimensions of innovation processes as a starting point. These dimensions are (1) socio-technical systems, (2) human actors, organisations, societal groups, and (3) rules and institutions. Anchorage, we suggest, could take place on either of these dimensions. By rephrasing these dimensions somewhat we will distinguish between three forms of anchorage, notably technological anchorage, network anchorage and institutional anchorage. These are discussed briefly below.

We will speak of *technological anchorage* when novel technical artefacts, concepts and practices in relation to the technology that are worked on in niches become more defined and take shape for the actors involved. Parts, that were separated before, may become linked to form a new configuration. These may subsequently become linked to other configurations and artefacts to make up new systems, possibly also linking up to new infrastructures.

Network anchorage means that the technology or concept becomes accepted (e.g. by producing it, using it or developing it further) by a wider range of actors. Besides simple expansion of the network, there are also other indications of network anchorage. These could include an increased involvement of regime players in niche activities, a strengthening of the coalition which is supporting the innovation process, intensified contact and exchange among actors within the network involved, and/or a formalization of the network (e.g. in terms of professionalization, commitments, degree of organisation, etc.).

Institutional anchorage of a new technology refers to a broad range of (still vulnerable) changes relating to institutions in a more sociological sense, i.e. with changes in the formal and informal rules and arrangements that orient human behaviour and (inter)action. Different categorizations of institutions exist. (e.g. Scott, 1995) Cognitive or *interpretative institutions* relate to how people make sense of themselves and the world around them. This includes, for example, the causal beliefs, visions, and problem views (as related to social values and interests) to which they orient their behaviour and actions. Also the identity that people ascribe to themselves and others can be seen as an interpretative institution. Translations as mentioned by Smith (2007, see previous section) can be seen as a shift in the interpretative rules applied to a situation. A second broad category includes *normative institutions*, which in our view includes *regulative* institutions. Here we speak of the translation of societal values into normative rules and aspirations (i.e. formal or informal rules about what is desirable and what not) that can be embedded in laws, regulations, policies and ethical standards. Finally, we can add *economic institutions* which include the

[20] The Dutch word ‘verankering’ (meaning anchorage) is used in these sources. In the Netherlands, this term is often used in writing and presentations to describe these processes but it has not been elaborated systematically.

rules and arrangements that govern economic activities and transactions connected to scarce resources. These encompass the way in which property and markets are organised and regulated, as well as the mechanisms and infrastructures through which exchange of goods is facilitated. Institutional anchorage then means that developments within a niche are translated into new or adapted (interpretative, normative or economic) rules that play a role, at least temporarily, in orienting the activities of both niche and regime actors.

The distinction between different forms of anchorage are analytical and in practice they may be difficult to disentangle. We expect, for instance, that technological anchorage will often be accompanied by network and/or institutional anchorage. We will analyse this further on the basis of a case study on energy use in glasshouse horticulture in the Netherlands to provide further insights into the processes of anchorage. We will thus explore whether this approach provides a productive inroad towards developing the theory of linking that Smith called for.

Concerning our case study, the Dutch glasshouse horticulture sector is responsible for 10% of the country's annual natural gas consumption. This has led to internal pressures (because of rising energy prices) as well as external pressures (to conserve energy and reduce CO_2 emissions) to bring this down. In recent years, this has led to a variety of 'alternative energy approaches' for the sector, some internal, some seeking to create new links with other sectors. This variety in linkage attempts makes this case very suited to study processes of anchorage.

Our case description is structured in the form of different episodes. At the end of each of these we will highlight the various forms of anchorage that took place, indicate how they related to each other and how this affected the niche-regime interactions. These analyses form the basis for the concluding section where we will generalise our findings from the emirical sections and present the contours of a theory of linking.

The case study is based on various technical and economic reports from research institutes and sector organizations. Since some of the developments analysed are quite recent and not yet documented we also rely on info from websites from the parties involved. This was supplemented with eight semi-structured interviews with representatives from growers (LTO-Glaskracht), project leaders, Horticultural Product Board, Agricultural Ministry, and academic research. These interviews were recorded and transcribed *verbatim*. This especially provided information on the reasons behind the developments described in written sources.

3. Towards an energy efficient glasshouse horticulture

3.1. Energy use in the glasshouse sector

After the traumatic experience of the 'famine winter' in the last year of the World War II the Netherlands developed strong agricultural policies to avert this risk for the future. One focal point was the development of a glasshouse sector to become less dependent on the often unreliable klimate to grow especially vegetables. This policy was so successful that the sector grew beyond what the country needed for its own supply and the Netherlands have become an exporter of vegetables as well as flowers and plants grown in glasshouses. (Wijnands et al. 2003)

Glasshouses convert sunlight into heat. During summer, when the air inside a glasshouse gets too hot, ventilation windows in the top are opened to get rid of excess heat. During winter, glasshouses also warm up on sunny days but on cloudy or cold days additional heat is needed to make the interior warm enough for plant growth.

Furthermore, most crops don't grow in winter because there is not enough light and to enhance growth huge light installations are used. This may also be applied during dusk and night.

Glasshouse heating installations in the Netherlands are fueled with natural gas. The sector also uses gas during spring and summer because of the CO_2 that results from burning gas. Plants 'inhale' CO_2 and 'exhale' oxygen (the opposite of the process in humans and animals) in a process called photosynthesis. In a glasshouse, growth is enhanced by feeding plants with extra CO_2, the same substance that is the main contributor to global warning. Gas is also burned in the fall, in this case to drive out excess humidity. (Interview Poot) Thus, the glasshouse sector uses gas year-round and in total the sector is responsible for about 10% of the Dutch natural gas consumption as well as 3% of its electricity use. In 2005, the sector emitted 6.1 Mtonnes of CO_2, about 3% of the Dutch total. (Van der Velden 2007; Koelemeijer and Kruitwagen, 2007)

The total area of glasshouses has grown to about 10 000 ha., a figure that has been relatively stable over the past decades. (LEI Data)[21] But under this constant figure major changes have occurred. On the international market, Dutch horticulturalists face competition from southern countries that are in a more favourable climatological position which requires less heating of the glasshouses. Especially with rising gas prices this became a significant factor in the past two decades. The Dutch have been able to remain competitive by continuous innovation in optimising the conditions for growth for a variety of crops and using advanced technologies to control the climate in a glasshouse. (AVAG, 2004; Vermeulen and Poot, 2008)

3.2. Aligning forms of anchorage in the regime: CHP

During the 1960s, after the discovery of huge national gas reserves in the north of the Netherlands, a nationwide grid for national gas was created. Since, natural gas has become a relatively cheap primary source for heating for housholds and industry, including the glasshouse horticulture (GH) sector. (Correljé and Verbong 2004) After the oil crises of the 1970s, however, oil and gas prices went up considerably which stimulated growers to start saving energy or find other ways to tackle the situation.

One option to do so sort of indirectly presented itself. In the 1980s, seeking to expand their business, glasshouse floriculturists started to grow flowers year-round. As winter light is insufficient for plant growth this required huge lighting installations, raising electricity needs and, hence, energy costs. To cut these costs, floriculturalists started to install 'combined heat and power' instalations (CHP) from the mid 1980s. (Van Vliet 2006)

This is a sort of mini-powerplant that burns fuel (in the Dutch case natural gas) to produce heat as well as electricity, both of which were used by the sector. Such installations were initially developed and used by large industries and further application was stimulated by government policies seeking to make more efficient use of energy. A 1989 electricity law allowed small producers to supply electricity to the grid and a dedicated programme to stimulate CHP was implemented which provided investment grants and a lower gas price for CHP. (Raven and Verbong, 2007)

This offered new opportunities for the GH sector. In the warmer and lighter months, their CHP installations sat largely idle but with the option of selling electriciy and stimulated by the government programme several growers started to supply

[21] 'LEI data' refers to data are taken from the LEI website. See references.

electricity to the grid during summer. Initially, lighting in winter using CHP was applied mainly in the floristry sector but because of international market developments it also spread to vegetables in the late 1990s. UK supermarkets, for instance, used to buy their tomatoes from the Netherlands during summer and from Spain during winter but to keep up quality standards they preferred to work with the same supplier year-round. This stimulated Dutch horticulturalists to apply lighting to grow other crops in winter as well which, in its turn, stimulated the use of CHP. (Interview Poot)

The liberalisation of the utility sector since the 1990s gave an enormous boost to this process. One effect of liberalistation was that new markets developed for buying and selling energy where horticulturalists could negotiate longer or shorter term contracts for buying gas and selling electricity. Many horticulturalists were quite good at this new game and in recent years quite a number of them have made more money in trading energy than from selling crops. (Interviews Smits and Van der Valk) An attractive condition for CHP was that the price received for electricity compared favourably to what horticulturalists paid for natural gas, the so-called 'spark spread', which stimulated further investments in CHP systems. In 2006, the sector became a net producer of electricity and early 2007, the total electric capacity of the CHP installations in the sector was about 1.7 GW, supplying some 10% of the country's total use. (Van der Velden and Smit, 2007)

In terms of our analytical framework, this episode firstly shows the *technological anchorage* of CHP installations. For the floriculturists, lighting became linked to their traditional heat production through CHP, constituting anchorage within the regime. Later, CHP became also linked to the national electricity system by integrating these systems in the national grid constituting a form of technological anchorage between regimes. This was largely stimulated by a form of *normative institutional anchorage*, notably government regulations that made possible and stimulated selling electricity to the grid.

This episode also shows different forms of *network anchorage*, first between the CHP installation world and the floricultural world. Once the floriculturists had used it successfully, other horticultuists also applied CHP which constitutes a further form of network anchorage within the regime. When the sector at large started to supply electricity to the grid the network further expanded to include the electricity world.

Following that, a gradual change in identity took place on the side of growers. They saw that they could make a lot of money from the energy they produced and developed energy production as a second business, i.e. a form *interpretative institutional anchorage* acompanied by *economic institutional anchorage*. What we thus see in this case is that all different forms of anchorage aligned and reinforced one another which led to CHP becoming a standard part of a horticultural enterprise.

3.3. Institutional anchorage of landscape pressure: 'sustainability requirement'

During the 1990s, sustainainable development became a rising public and political issue. Various sectors, including the GH sector, came under pressure to do something about emission of polutants, energy use, use of raw materials, use of pesticides etc. Attempting to achieve this in a coherent and non-disturbing way, voluntary agreements were concluded between government bodies and representatives from various sectors. These agreements specified targets for the future (e.g. 2010) providing room for businesses to work on various issues in succession rather than on everyting at the same time.

Thus, in 1997 the GH sector concluded a voluntary agreement with provisions for the use of minerals, crop protection, energy efficiency and the use of sustainable sources of energy. A steering committee by the name of Glami[22] was created that should help realise the targets. (Interview Smit) Glami expressed a need to change the rules applied to the GH sector (to produce not only in a cost-effective way but also in sustainable way) which constitutes a form of normative institutional anchorage.

In 2002 the Glami agreement was followed by policy regulations (Besluit Glastuinbouw, 2002) that set standards for each area (energy, minerals) for individual companies for successive years. Energy reduction targets were defined via an energy efficiency index that was set at 100 in 1980. By 2010, this should be reduced to 35, 4% of which should be generated from sustainable sources, implying a reduction of 65% over a period of 30 years. In the year 2000, the realised index was 56 and in 2005 it was 46 meaning that the reductions achieved in practice were more or less on schedule. (Van der Velden and Smit, 2007)

In the late 1990s, the need to reduce CO_2 emissions became a rising star on the sustainability agenda. The Dutch government has set a national target of 30% reduction of CO_2 emissions by 2020 compared to 1990. (Koelemeijer and Kruitwagen, 2007) The glasshouse sector was also expected to contribute its share which started a variety of new developments. One of the most important changes is that horticulturalists themselves have started to recognise the need to reduce energy use and CO_2 emissions. (Interviews Maters and Van der Valk)

It is evident that the need to save energy is large stimulated for economic reasons because of rising gas prices but according to several interviewees the need to reduce CO_2 emission is also clearly acknowledged in the sector. Thus, *economic institutional anchorage* and *normative institutional anchorage* seem to reinforce one another although it is difficult to disentangle them.

3.4. Aligning forms of anchorage in a niche: semi-closed glasshouse

3.4.1. Semi-closed glasshouse

In the period 1984-1992, inspired by plant-growth reasons, scientists had been working on the concept of a closed glasshouse. Keeping a glasshouse closed helped to keep insects out and CO_2 in which enhanced plant growth. However, it appeared too difficult to cool a closed glasshouse in summer and the development was stopped. (De Gelder and Kipp, 2005) In the late 1990s this work was picked up again for energy reasons by linking it to developments in the building sector.

In the 1990s, the building sector started to use a combination of heat exchangers with underground heat and cold storage. A heat exchanger is a device with tubes through which water is pumped. Doing this with cold water in a warm atmosphere in summer resulted in cooling down the air and warming up the water. This warm water was stored in underground layers called aquifers. During winter, the warm water was pumped up for heating purposes. In the same way cold water was stored in winter and pumped up in summer for cooling. (Verbong 2001)

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[22] Glami = Glastuinbouw en Milieu (Horticulture and Environment). Specifics can be found at: http://www.glami.nl/

In the late 1990s, scientists at WUR[23] (Wageningen University and Research Centres) sought to apply such a scheme to a glasshouse. They teamed up with Ecofys, a large consultancy firm that specialised in renewable energy and energy saving. Ecofys had no experience in the glasshouse sector but wanted to move in that direction and created a subsidiary, Innogrow, to develop a working prototype. This led to a design that used a large central heat exchanger placed in the front of the glasshouse and a ventialation system with hoses that led the warm or cool air through the glasshouse. This 'Glasshouse of the Future' was exhibited at the 2002 *Floriade* world horticulture fair, a large prestigeous exhibition visited by the public as well as stakeholders from the sector. (Van Gelder and Kipp, 2005, p.11)

This raised considerable interest and the following year a practice demonstration was carried out. In 2004, the results were promising enough to stimulate one grower to install it in his own glasshouse. The first technical results indicated that this system allowed a considerable amount of energy conservation while there was also some rise in productivity because of higher CO_2 levels. Articles on these results appeared in business journals and meetings were organised to inform growers. This stimulated interest from horticulturalists as well as suppliers of technology who started to develop and offer new variations. As a result, about a dozen horticulturalists started with some form of (semi-) closed glasshouse concept in 2005-2006. A government programme to stimulate energy conservation provided subidies that lowered the investment costs. (PT and LNV, 2006)The remaining costs would have to be recooped by lower energy costs and higher productivity.

Innogrow's initial design was a 'Closed Glasshouse' which they registred as a trademark. Such a glasshouse still gets too hot in summer (due to the inefficiency of catching and storing heat) and requires an additional cooling system which adds to te costs. A cheaper variant was to allow for some ventialation although far less than in a conventional set-up. Such designs are called 'semi-closed glasshouses' (SCG). (Innogrow, 2005)

In analytical terms, we initially see a form of technological anchorage when a heat exchanger becomes linked to a glasshouse energy system to define a closed glasshouse. This was accompanied by network anchorage, initially between scientists and an engineering company in a niche. The network then expanded to include half a dozen growers and suppliers of glasshouse installations who also became part of the niche because they relied on protection in the form of government subsidies. This niche expansion enhanced the possibilities to learn about whether and, if so, how the concept could be made to work in practice.

3.4.2. Energy producing glasshouse

Concurrently with the development of the semi-closed glasshouse a more radical variant was also developed. In the late 1990s, the Dutch national advisory council for agricultural research (NRLO) carried out various desk studies on what was called a "climate neutral glasshouse horticulture". In 2000 the NRLO was succeeded by an organisation with a more developmental than advisory character called in short the *InnovationNetwork*. At the same time the sector's branche organisation *LTO* (later *LTO-Glaskracht*) saw a need for major innovation in the sector to tackle competitive and energy challenges and created a programme and organisation by the name of

[23] Wageningen University has traditionally specialised in agriculture and animal husbandry sectors. In The Netherlands, these are large economic sectors and next to the university there were a variety of more specialised research centres with a more practical orientation. In 1998 the university and these research centres merged to form WUR.

SIGN (the Dutch acronym for Foundation for Innovation in the GH sector). (Grin and Van Staveren, 2007, Ch.3)

Early 2001 SIGN and the InnovationNetwork organised a joint meeting to develop an innovation agenda for the GH sector. They developed a long-term programme by the name “Glasshouse Horticulture 2020” and identified five themes to work on, one of which was energy. The people responsible for this theme were not afraid to think radical and started with a paradigm shift: rather than seeing the GH sector as an enormous consumer of energy they saw it as a 10 000 ha. big solar collector. Using heat exchangers combined with heat and cold storage as in a semi-closed glasshouse would make it possible to harvest enormous amounts of heat during summer, store it underground to be used in winter. (Roza, 2006)

In 2001, the programme managers talked to a variety of actors in the sector to gain support for their ideas. Stakeholders from various corners of the sector lend a willing ear but were quite unanimous in their judgements: “It’s nonsense.” (Van Oosten and Koehorst 2007; Interview Van Oosten) The only positive responses came from outside the GH sector, one from an Akzo Nobel employee who worked on a new type of heat exchanger by the name of *Fiwihex* which he thought would be perfectly suited for the purpose. A representative from KEMA, a Dutch research organisation for the electricity sector, also responded positievely. They became part of the programme team to develop the concept further, using the Fiwihex as a central element. (Roza, 2006)

WUR scientists calculated that this could result in a net-production of energy on a year-round basis. (De Zwart and Campen, 2005) For that reason it was called the Energy Producing Glasshouse (EPG). Various scenarios were developed on how to use the energy produced by the glasshouse. In some of these, the energy was used within the sector but in the most radical scenario the heat was used to warm nearby houses. The glasshouse would thus become part of a broader local system of use and supply of energy called an *Energyweb*. Later studies within the programme suggested that a 1 ha. glasshouse could warm a hundred houses. (Roza, 2006, p.26) With a total GH surface of 10 000 hectares the theoretical capacity would be to warm a million houses, over 10% of the Dutch stock.

On the technical side, in contrast to the semi-closed glasshouse where a large central heat exchangers was used, a Fiwihex was a small device of which a large number (about 250 per ha.) would have to be placed in a glasshouse. The advantage was that no hoses would be needed to pump the warm or cool air through the glasshouse. In 2003, after some small scale tests and further developmenent, WUR scientists considered this a promising concept. Their positive report was important to secure further funding. (Grin and Van Staveren, 2007, pp. 41-42)

The next step was to demonstrate the concept on a larger scale. After some internal deliberations it was decided to go directly to a real life size pilot, notably 5 000 m^2, i.e. 0,5 ha. Since this was larger than existing research facilities the pilot was carried out in an existing business owned by an interested horticulturist. This project started in 2006. (Roza, 2006, p.31)

In analytical terms, we initially see a form of technological anchorage in which the Fiwihex heat exchanger becomes linked to a glasshouse energy system which subsequently became conceptually linked to an energyweb. Network anchorage of sector actors, however, appeared quite problematic, with various stakeholders rejecting the concept. Eventually, one grower became linked who, because this was realised via subsidy protection, became part of the niche.

3.4.3. Research programme and actionplan

During the early 2000s, the concept of transition management became quite popular in the Netherlands. The general idea is that in many sectors system innovations are needed to achieve sustainability which should be stimulated and guided by specific forms of governance. This was also taken up for the GH sector. Around 2005 representatives from the Ministry of Agriculture as well as from the sector concluded that a variety of new initiatives were germinating and that some sort of co-ordination would be needed to reap the full benefits of this for the sector as a whole. To facilitate this, the ministry together with the Horticultural Product Board established a programme by the name "Kas als Energiebron" ("Glasshouse as an Energy source"; hereafter called GaE programme) and provided substantial funds, € 5.6 million in 2007. (PT and LNV, 2006)

The programme defined six so-called transition paths, including solar energy (using heat caught by glasshouses and production of electricity), biofuels, energy efficient crops and growth strategies, light (efficient use of daylight and energy efficient lamps). (PT and LNV, 2006, p.3) These examples reflect a broad portfolio of possible solutions for two reasons. The first is that it was still unclear what the practical potential of each option was. The second is that the managers of the programme did not think there would be one solution. The glasshouse sector is quite varied with thousands of companies growing hundreds of different types of crops, plants and flowers and various concepts would have to be tailored to specific needs to satisfy this diversity. (Interview Smits)

The programme makes a distinction between what are seen as forerunners and the sector as a whole, in 2007 some 5 000 businesses. Until that year, some 15 of them had started with different variants of semi-closed glasshouses, all of which used heat exchangers combined with heat and cold storage in aquifers. There was a considerable interest in the sector as appeared from the 60-70 applications for an investment subsidy in 2007. The rapidly rising gas prices in 2006 are likely to have stimulated this interest. Applications were for the construction of 140 ha. of new glasshouse surface, all of which were awarded. (PT and LNV, 2007, p.6) Sector representatives considered this a high interest given that about 400 ha. is renewed each year. (Interviews Smits and Van der Valk)

In further developments, the sector representative *LTO Glaskracht* and the *Stichting Natuur en Milieu* (Nature & Environment Fund) became also linked to the semi closed glasshouse. In the mid-2000s they had started to interact on issues related to the environmental impact of the GH sector which, in 2007, led to a joint 'Actionplan for a climate neutral glasshouse horticulture'. The plan specifies a 'transition package' including the target of a 45% reduction of CO_2 emissions by 2020 compared to 1990. For 2010, the plan specifies that 400 ha. of glasshouse (i.e. 4% of the total surface in the Netherlands) should be 'semi-closed'. (SNM and LTO Glaskracht, 2007)

3.4.4. Synergie businessplatform

In the Netherlands there are several national programs that seek to combine scientific research on innovation processes with practice oriented programmes to induce system innovations towards sustainability. Within these programs there are various projects dealing with more specific topics. One of the national programs, Transforum, deals with the agricultural sector and within this one concrete project by the name of

Synergie (the Dutch writing of ‘synergy’) targets the GH sector. Synergie is linked to the ‘Glasshouse as an energy source programme’. (Boonekamp, 2006)[24]

The platform aims to bring together scientific knowledge developed in research institutions with knowledge developed in practice by the horticulturalists. This is a challenge in itself because these two groups partly speak different languages. A horticulturalist may say that he can see that a plant doesn’t feel happy or describe that a leaf feels crispy but that’s not the kind of information that a scientist can work with. These differences in language are one of the reasons that the links between research and practice leaves much to be desired. (Interview Maters)

The platform started early 2006. Horticulturalists working with new energy systems started to meet regularly with researchers and discuss their experiences and various other issues. Gradually, they have learned to speak each other’s language and come to a fruitful exchange. Meeting each other regularly was also important to build confidence between growers and researchers. Especially since a (semi-) closed glasshouse allows to control various relevant parameters (temperature, CO_2 level, humidity, light) it was considered important that horticulturalists work closely together with scientists to find new optimal growth conditions. Suppliers are also part of the platform to ensure that new technologies can indeed be produced at a price that makes it interesting for a wider group of followeres to acquire these installations. (Synergy website; Interview Maters)

3.4.5. Aligning forms of anchorage in the niche

Through the GaE programme the network related to semi-closed glasshouses expanded further to include regime actors such as the Horicultural Product Board and the Ministry of Agriculture while the ‘Actionplan’ further enrolled *LTO Glaskracht* and the *Nature & Environment Fund*. Still, the SCG development took place within a niche as its survival was dependent upon various forms of protection such as subsidies. The *Synergie* business platform not so much expands the niche but strengthens co-ordination within it which, as we have defined it in section 2.4, also contributes to network anchorage.

The GaE programme, the Actionplan as well as the business platform provided a specific way of framing future development that became more widely shared in the sector (given the large number of subsidy applications), which constitutes an example of interpretive institutional anchorage in our analytical framework.

Thus, several forms of anchorage (technological, network and institutional) were starting to align although the semi-closed glasshouse was still supported by subsidies and, therfore, this contributed to niche development rather than regime development. It seems that to achieve the latter one important form of anchorage, economic institutional anchorage, was still missing.

3.5. Anchorage opening up new possibilities: adiabatic cooling

The GaE programme explicitly targets a system innovation, with the goal that after 2020 all newly built glasshouses will be climate neutral. Interestingly, after the semi-closed glasshouse had anchored on several dimensions this started new developments that could also be used in existing installations which might compromise the system innovation ambition.

One example is adiabatic cooling. In a closed glasshouse, the heat caught in summer is stored in an aquifer. In practice, however, these glasshouses still get very

[24] Detailed info can be found at the Synergie website: http://www.synergieplaza.nl/

warm necessitating some sort of ventilation or cooling. As in the new thinking ventilation was not attractive (which would necessitate continuous CO_2 feeding to enhance growth) there was a search for effective, inexpensive forms of cooling. An interesting option apeared to be to make use of so-called adiabatic cooling. In this approach, small droplets of water are sprayed into the glasshouse creating a light mist. Due to the high temperature these droplets vapourize quickly which has a cooling effect, so-called adiabatic cooling. This increases the humidity in the glasshouse but this might even benefit growth as it does in a rainforrest. (Cli Mate, 2008; Interview Smits)

Thus, adiabatic cooling was initially applied to compensate for the lack of ventilation in a semi-closed glasshouse but once demonstrated it appeared to have more general advantages in the sector. Such a mist installation has a relatively short payback time and various horticulturalists have started to install it in a conventional glasshouse. Thus, a development that was initially started as an overall concept targetting system innovation led to the technological anchorage of a 'spinn-of' that can be seen as a form of incremental innovation. Network anchorage followed quickly when it was picked up by various growers in the regime. (Interview Smits)

But this incremental step does not mean that the possibility of a system innovation has evaporated because a higher level of humidity contributes to another development path. A closed glasshouse makes it easier to control CO_2 levels and, hence, plant growth. However, there are various physical parameters that affect growth, the most important of which are light, temperature, CO_2 concentration, and relative humidity. A closed greenhouse with a mist installation, initially intended for cooling, makes it easier to control all these parameters. At present, growing crops is based on practical experience on what the optimal combination of these parameters is but it is now possible to stretch these parameters considerably further than in a conventional glasshouse. With these new technological options horticulturalists may have to learn anew how to grow crops. (Dieleman et al., 2007)

3.6. Anchorage between systems – Energywebs

The Energy Producing Glasshouse project suggested the possibility of using heat generated in glasshouses to warm houses. In analytical terms this would imply linking two systems that hitherto were separate. In 2001, when the EpG programme managers tried to get support for their ideas, including heating houses via so-called energywebs, they were turned down by all sector actors. One of the arguments from the ministry was that the glasshouse sector was about producing crops, not about producing energy. (Interview Van Oosten)

Although initially turned down by the sector, the energyweb concept came back on the agenda via the semi-closed glasshouse route. It appeared that these glasshouses provided more energy in summer than was needed in winter. One of the first applications was in the sector itself. In 2006, Prominent, a group of 22 growers, built 9.3 ha. of new glasshouses of which 3.4 ha. used the Innogrow Closed Glasshouse concept and the other 5.9 were conventional 'open' glasshouses. Excess heat stored in summer from the 3.4 ha. was used to heat the whole 9.3 ha. area in winter. (SenterNovem, 2006)

Other growers, however, started to look for possible external users for their heat. In 2006, two horticultural enterprises teamed up with Volker Wessels, a large construction and infrastructure company, to make an offer for heating 2 800 new houses in the village of Waddinxveen in the western part of the Netherlands. (InnovatieNetwerk, 2007) The outcome on the bid at the time of writing was still unsure. In Venlo, in the south of the Netherlands, a project did take off. A tomato grower built a new glasshouse by the name of Greenport which, as of 1 January 2008, warms a nearby nursing home. (SunnyTom, 2007)

These initial moves open up a range of new possibilities. Firstly, the managers of the GaE programme have raised their ambitions: by 2020 the glasshouse sector should not only supply sustainble electricity but also sustainable heat to other sectors. (PT and LNV, 2007, p.3) But this line of thinking can also be reversed. The sector could also use heat generated elsewhere to warm glasshouses. Various industries now have excess heat that is discharged as warm water into rivers or canals or via cooling towers into the atmosphere. (Interview Smits) Thus, the energywebs have come back on the agenda.

This is not only a thought exercise because the first moves in such a direction have already been made. In 2007, plans were being developed for the region of the 'Westland' between Rotterdam and The Hague, that has the highest concentration of glasshouses in the Netherlands, to develop a variety of smaller energywebs which, in a later stage, might be linked to create larger webs. The city of the Hague, for instance, is developing plans to use geothermal heat to warm houses and such a scheme might later be connected to a developing grid in the Westland. (interview Smits)

Thus, initial technological anchorage that links glasshouses to wider energywebs has taken place. A growing variety of actors is tinkering with this concept constituting also network anchorage. This is accompanied by interpreative institutional anchorage in which the glasshouse sector is no longer seen as self supporting but part of a wider system of producing and supplying energy. Admittedly, the links in this developing niche at the time of writing were quite weak but the interesting point about this episode is that it shows that anchorage that initially fails (when the ideas of the EpG people were turned down) may find other routes that are more successful.

4. Conclusion

In this section we will systematise and reflect upon the findings that were presented and evaluate the usefulness of our perspective on niche-regime interaction and anchorage. Furthermore, the emphasis on ongoing innovation processes allows us to draw some general conclusions on possibilities to stimulate system innovation. These will be addressed in the final part of this section.

4.1. Crooked pathways of anchorage

In section 2.4 we proposed several forms and expressions of anchorage to characterise interactions between niche and regime. We distinguished between technological anchorage, network anchorage and various forms of institutional anchorage (interpretative, normative and economic). We have seen that it is indeed possible to describe the recent history of events and the progression in the innovation process in terms of these different forms of anchorage as we demonstrated technological as well as network and institutional forms of anchorage.

More important than signalling that different forms of anchorage can indeed be identified is that our description of different episodes of anchorage results in a meaningful story. This story shows that different forms of anchorage are closely intertwined and logically connected and that an earlier episode of anchorage creates the conditions for later forms of anchorage. This is not to say, however, that such trajectories are intentional or amenable to deliberate planning and design. At the beginning of the journey, for example, we see that for cost-reduction purposes some growers were already using CHP technologies. This coincided with a dynamic in the energy regime towards liberalising the energy market which, in turn, resulted from a 'landscape' level international trend towards market liberalisation. The interaction between this technological and (economic) institutional dynamic resulted in a situation that was conducive to growers starting to look at themselves as energy producers, a shift in identity that can be seen as a form of (interpretative) institutional anchorage. Although this was not initially associated with the later notion of 'glasshouse as an energysource', this identity change certainly helped to pave the way at a later stage.

In the empirical description several of such interdependent sequences can be discerned. This is represented in Figure 4 which builds on Figure 3 and zooms in to the area where one niche intersects with the regime. In Figure 4 we attempt to visualise the various forms of anchorage, the 'locations' of anchorage and the most relevant influences and pathways. What the figure basically shows is that various forms of anchorage may follow one another via very crooked paths.

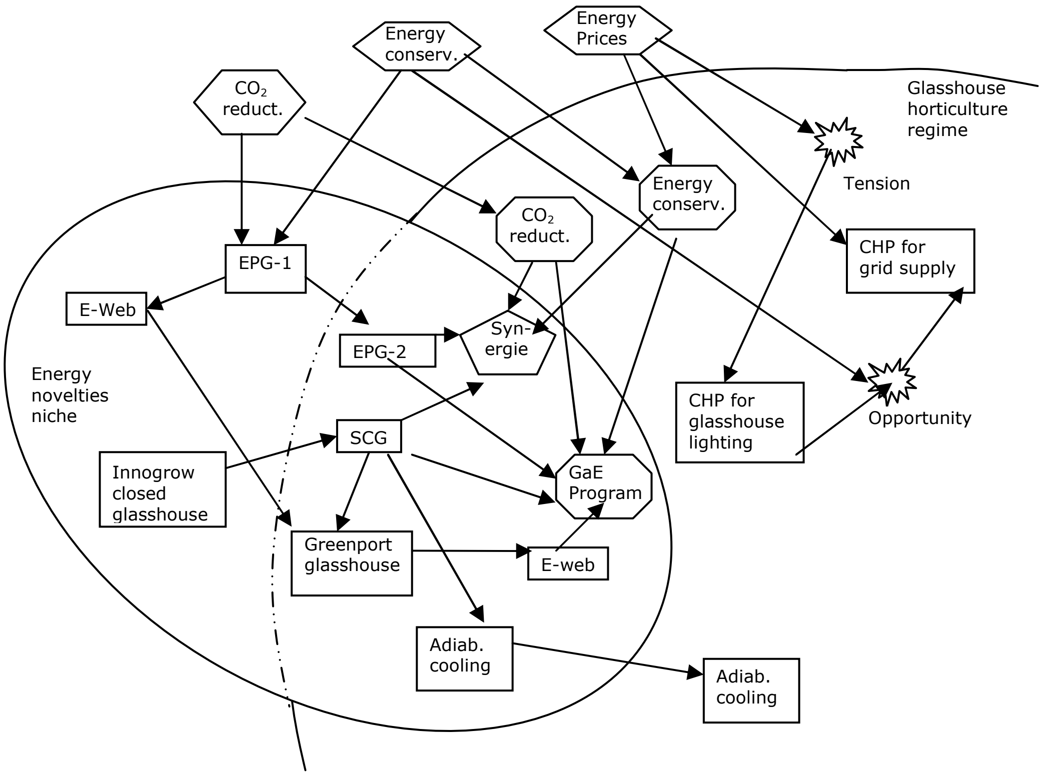

Figure 4. Processes of anchorage. The rectangles denote technological anchorage, the pentagons network anchorage and the octagons institutional anchorage. As in figure 3, the hexagons denote landscape pressures.

What emerges from the above is that different forms of anchorage occur in a relatively capricious pattern, where one form of anchorage (or the lack or failure of it) offers opportunities for subsequent dynamics to occur. In line with earlier work on MLP, our case-study suggests that landscape pressures play an important role in inducing niche- as well as regime developments. Growing political and societal awareness that CO_2 emissions must be reduced, for example, has affected virtually all developments described, on the niche as well as the regime level. Thus, landscape pressures can set things in motion but that is not yet anchorage. Anchorage implies that different actors link up to a novelty and that this link has some durability. The case provides a variety of instances of this happening. Building further on some of the examples mentioned in the previous paragraphs we can see patterns like:

- *Translation*: e.g., of Innogrow closed glasshouse into semi-closed glasshouse. Also translation of semi-closed glasshouse (SCG) into a more radical concept (EpG) with the addition of the concept of energyweb. The latter initially refuted but later linked to SCG. This coroberates Smiths' findings on translation referred to in section 2.3.
- An '*opportunity*' that presents itself after a previous anchorage, e.g. to sell electricity after installing CHP, initially for internal use. Subsequently growers find out they can also supply to the grid making many of them energy-converters (gas into electricity) and traders.
- *Internalisation*: The need to reduce CO_2 emissions and the ambition of climate neutrality first were an *outside pressure* that was put on the agenda primarily by outsiders and affected niche developments like EPG. In the early 2000s it became internalised within the regime and since it has clearly anchored there.
- *Alignment* of various forms of anchorage seems to enhance durability. In the CHP case, all forms of anchorage aligned and it became a standard part of a horticultural business. In the case of semi-closed glasshouses, only one form is missing, notably economic institutional anchorage. This has led to a variety of activities in the niche but it is not (yet) picked up in the regime at large.

This limited summing up already suggests that processes of anchorage can follow a variety of crooked paths. The research challenge in further work is to find some order in this and possibly distinguish a limited set of characteristic patterns but this can only be done on the basis of a wider variety of case studies.

One thing that we do want to stress is that anchorage can take place under a variety of pressures and tensions as well as *opportunities* (e.g. selling electricity once CHP has anchored). The initial MLP studies typically stress (landscape) pressure only but in Figure 3 we acknowledge this duality by seeing both tensions (T) and opportunities (O) as a possible starting point for change and and our empirical study gives various examples of the latter as is also indicated in Figure 4.

4.2. Locating anchorage: critical role of hybrid forums

The relatively positive dynamics in this case may be related to the fact that we are not just dealing with the horticultural regime, but also with the energy regime. In terms of the actors and networks involved, therefore, we are likely not only to encounter 'insiders', but also 'outsiders'. Various studies have stressed that radical innovations usually come from outside the regime and are initially developed by entrepreneurs and pioneers. (e.g. Constant, 1980; Utterback, 1994) Van de Poel uses the term 'outsiders' for these actors who feature two main characteristics: (Van de Poel 2000, p. 384)

1. They are outside or at least marginal to the regime;
2. They do not share some of the relevant rules with respect to technical development.

When looking at the actors that played an important role in furthering the radical innovation process in our case-study the following categories stand out:

1. Suppliers of glasshouse installations. Because they also operate in other sectors than the GH sector they are an important channel for introducing innovations from other sectors into the GH sector (e.g. from the building sector);
2. ‘Pioneer-growers’: they are definitely regime actors who want to make a profit from growing crops but they are at the same time prepared to take risky, innovative steps to satisfy societal concerns;
3. Horticultural Product Board. They clearly seek to guard the vital interests of the sector but are at the same time very sensitive to societal concerns, and actively stimulate innovation through programmes such as SIGN;
4. The semi-governmental innovation intermediary *Innovation Network,* which is affiliated to the Ministry of Agriculture and who introduced the vision of an Energy Producing Glasshouse.

These actors clearly do not satisfy both of Van de Poel’s criteria. They are anything but marginal to the regime and/or they do share (some of) the relevant rules. On the other hand, they also have a deep commitment towards the realisation of (radical) change to satisfy societal concerns. Interestingly ‘real’ outsiders such as players in the energy sector proper do not play a very active and prominent role, even if (economic and legal) institutional developments in the energy sector are of critical importance in the background.

To account for this we define an intermediary category which we call *hybrid actors*. They form a category between insiders and outsiders, displaying some important characteristics from each of them.

Coming back to anchorage, then, it is exactly these *hybrid actors* that play a crucial initiating role. They operate at the intersection between niches and regime in figure 4. In this case, they do so in various network settings, e.g.

- several pilot projects;
- the ‘Glasshouse as an Energysource’ programme;
- meetings between the *Nature & Environment Fund* and *LTO Glaskracht* that have led to the ‘Action programme for an energy neutral GH sector’;
- *Synergie* businessplatform.

All these activities take place within the overlapping area between niche and regime. (cf. Figure 4) These settings are characterised by relatively stabilised networks (i.e. forms of network anchorage) and take the form of forums where regime and niche developments come together at the most concrete level. We will call these networks *hybrid forums*.

With reference to the different forms of anchorage discussed, this case-study suggests that both technological and institutional anchorage seem to go along with, and is in most cases are preceded by, network anchorage. This is not all that surprising as network formation has been often identified as a critical process in bringing about innovation (Callon et al., 1986; Leeuwis, 2004). This study specifies that further by suggesting that hybrid actors which operate in the context of stabilised hybrid forums play an important role in stimulating anchorage and radical innovation.

In addition, the hybrid forums are of interest in that they can be seen as a specific ‘location’ where anchorage takes place. When distinguishing niche, hybrid forums and the regime, anchorage can in principle take place in either of these. Our study provides some indication that anchorage in a hybrid forum can be an important intermediary step in moving from niche to regime.

4.3. Multi-regime dynamics

This study shows that landscape factors like the need to reduce CO_2 emissions and energy consumption have an impact on the dynamic in the niche as well as the regime. This has been acknowledged in the MLP literature right from the beginning but the model with the three levels (figure 2) obscures this important feat. Similarly, in the original MLP model, the energy consumption by the GH sector would be seen as a regime feature while the overall dynamic of the energy sector would be seen as a landscape factor since it affects a broad variety of regimes. This study shows, however, that the dynamic in the energy sector and that of the GH sector have become much more closely interlinked as increasing numbers of growers became suppliers as well as buyers of energy.

In analytical terms we suggest that the these developments take place at an intersection between two regimes, the GH regime and the electricity regime. Each of these regimes largely has its own dynamic but there is an overlapping section where they influence one another. Thus, we are looking at interactions between two regimes. There are only a limited number of studies that describe and conceptualise such 'multi-regime' dynamics (e.g. Raven and Verbong, 2007; Van Mierlo, 2002). Van Mierlo focuses on one specific aspect, notably how the confrontation of actors from different regimes who cooperate and have conflicts within pilot projects stimulates niche branching. In our analytical terms this would constitute a breaking up of anchorage but our case study (out of analytical choice) provides hardly any examples of this.

Raven and Verbong analyse multi-regime processes at a rather high level of aggregation and have developed a typology in which they distinguish four different interaction patterns between two regimes, notably: (1) competition (2) symbiosis (3) integration, and (4) spill-over. With our interest in processes of anchorage, however, this model is too crude. By zooming in to a more micro level we see different dynamics and patters occurring at different moments in the process. E.g. we see competition (between growers and utilities both supplying electricity) as well as integration (e.g. via energywebs). It would be interesting to explore in further work how processes of anchorage could help to understand multi-regime dynamics, also looking at breaking up of anchorage and relating this to Van Mierlo's work.

4.4. Distinguishing incremental and radical innovation

Our study of anchorage also sheds some further light on the distinction between incremental and radical innovation, at least when looking at 'innovation in the making'. In a rather simplistic distinction between the two, incremental innovation takes place in a regime, gradually transforming the technical side but hardly affecting the institutional side. In early MLP studies it was argued that system innovation largely comes from radical alternatives in niches breaking through in the regime, transforming not only the technical dimensions but also the institutional dimensions and the actor-configurations. (E.g. Geels, 2002, 2005). Geels and Schot (2007) have shown, however, that this distinction is too simple. By analysing a variety of cases on system innovations (or transitions) they present a typology of four what they call 'transition pathways'. In one of these pathways, niches play no or only a minor role and a pattern of system innovation largely develops within the regime.

Geels and Schot provide useful insights into different patterns of system innovation but they do not question the distinction with incremental innovation. This is probably the result from looking at very long-term processes leading to clear distinctions after leaving out various micro-level developments. If we zoom in to this micro level and ongoing processes, however, the distinction is less clear. Let us highlight some examples from our case.

The concept of semi-closed a glasshouse had explicit system innovation ambitions. The general idea was to use glasshouses to catch and store energy in summer for later use in winter rather than finding ways to get rid of excess heat. To be able to do so, some additional form of cooling appeared necessary leading to the development of adiabatic cooling. The latter concept, however, appeared to be of use in a conventional glasshouse as well as it allowed keeping windows shut and provide for more ‘controlled’ growth. Thus, a development, that started with clear system innovation ambitions became modified (translated, in Smith’s terms) into a system with incremental ambitions notably to enhance plant growth.

Another example shows the reverse process. CHP was initially used in the floriculture sub-sector with incremental ambitions, notably to reduce the electricity bill. Subsequently, the electricity was supplied to the grid and provided an extra source of income. The liberalisation of the energy sector offered new possibilities to play with gas and electricity prices and several growers became energy traders as well and thus became players in a regime different from their traditional one. Building further on this, various sector-actors have started explorations to create energywebs, a concept that was rejected only a few years before. These developments clearly reflect a process of system innovation with changes in technology as well as institutionalisation.

These examples illustrate that a development that starts with system innovative ambitions can be transformed into an incremental path of change and *vice versa*. Apparently, it is very difficult to distinguish between the two when one is in the middle of it. This not just a matter of having insufficient overview of what is happening, but also related to the fact that unforeseen dynamics and coincidences occur, which fundamentally reduces the feasibility of predicting the direction that developments will take.

4.5. The meaning of projects and intervention

The realization that what turns out to a system innovation can only be identified *ex-post* is perhaps an open door. Nevertheless our observations are relevant for practitioners and project funders who frequently make early judgements and claims about the nature of innovation efforts that they are involved in. It contains a warning that one should not be overtly optimistic about the scope for planning and controlling system innovation processes. However, this does not render deliberate intervention and projects meaningless. In fact, we see that the pathways outlined involve and weave together a range of networks (including hybrid forums) and developments that are somehow part of (pilot) projects, programmes and interventions. Some of these are indeed directed at stimulating Energy Producing Glasshouses, while other building blocks derive from (simultaneous or past) developments and projects in other domains and spheres. Interestingly, also projects that were in their own time looked at as a ‘failure’ may have positive spin-offs and be brought back into the lime light. An example of this are past projects aimed at building ‘closed glasshouses’ as a strategy to manage pests and diseases and prevent air pollution. These goals were not achieved at the time, but the glasshouse designs developed for these purposes have at a later stage inspired and influenced the development of glasshouses with heat storage systems.

Thus, we can say that projects and interventions matter, albeit at times - and perhaps quite often - in ways that were not intended or anticipated. (Elzen et al. 2004).

They are part of a complex (selection) environment in which actors act, strategise and take initiatives, which results in the development of elements and building blocks that may become linked and which offer opportunities for change. This is in line with both evolutionary understandings of innovation (e.g. SNM; Hoogma et al., 2002) and approaches which build on theories about complex dynamic systems (Prigogine & Stengers, 1984; Loorbach, 2007; Leeuwis & Aarts, 2008). In the Western context, 'projects' are a dominant mode of sourcing resources, action and energy, and without them it is doubtful that much effort would be invested in re-organising the glasshouse horticultural sector.

4.6. Epilogue

What we set out to do in this paper was to argue that in order to understand system innovations better we need to take a closer look at what happens at the area of overlap between niche and regime. We agreed that we need what Smith calls a 'theory of linking'. Inspired by Loeber (2003) we have used the term anchorage, and explored the usefulness of several forms of it in analysing an ongoing system innovation trajectory. We concluded that the analytical concept helps in identifying pathways and patterns of anchorage, and was instrumental in signalling the significance of *hybrid actors* and *hybrid forums* in fostering anchorage at the area of overlap between niche and regime. Moreover, the analytical framework resulted in a new and less hierarchical representation of the multi-level perspective, which proved helpful in mapping and visualising the messy dynamics of innovation trajectories. Thus, we argue, we have made a useful next step towards the theory of linking that Smith called for. In further work, a wider variety of cases would have to be anlysed to systematise patterns of anchorage and the role of hybrid actors and forums therein.

The work presented is not only of academic relevance. In the introduction we started by pointing to the widely shared ambition to induce system innovation to contribute to sustainability. To be able to do so, we argued, we need a better understanding of system innovation and, especially of what happens at the intersection between niches and regimes. For practitioners, the important role that hybrid actors and forums seem to play could inspire the development of future interventions and projects. Moreover, the demonstrated messiness of innovation trajectories might inspire practitioners to rethink the scope and nature of projects required (e.g. more variety, less predefined outputs, more realistic expectations) and the way in which they are evaluated and monitored.

Finally, after zooming in on the intersection between niche and regime, the subequent challenge, of course, is to zoom out again and understand how anchorage can eventually contribute to system innovation. That challenge is far beyond the scope of this article but with this analysis we have sought to provide some useful analytical tools for ourselves and others to take up that challenge.

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5. Normative contestation and transition pathways 'in the making': Animal welfare concerns and system innovation in pig husbandry

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Abstract
Previous studies of system innovations mainly focused on historical cases that were driven by commercial motivations of pioneers and entrepreneurs. This article investigates system innovation that is driven by normative concerns, such as sustainability or animal welfare, initially formulated by outsiders such as special-interest groups. The conceptual framework enriches innovations studies with insights from social movement theory, which help analyse the build up of normative pressure (framing, resource mobilization, political opportunity structures). This pressure only leads to system innovations, however, if it aligns with regulatory, market and technology development processes. In our case study we will explore how different alignments lead to different transition pathways. The research design consist of a comparative case study of pig husbandry systems. One case analyses the sub-sector of dry (i.e. pregnant) sows where normative pressures, after several decades, led to the targeted changes. The second case concerns the sub-sector of pig fattening where normative pressures were less successful. The difference is partly explained by the normative pressure for dry sows being larger than for fattening pigs. The other part of the explanation concerns the *degree* and the *timing* of alignment with economic, regulatory, and technical developments which also explains the particular transition pathways followed in both cases.

Keywords: System innovation, Transition pathways, Sustainability and animal welfare, Agriculture, Normative directionality

1. Introduction

This article adds to the debate about socio-technical transitions and system changes (Kemp et al., 1998; Elzen et al., 2004; Smith et al., 2005), in particular to the topics of normative directionality and transition pathways. Many historical cases of transitions were driven by commercial motivations of pioneers and entrepreneurs, e.g. cars replacing horses (Geels, 2005), mechanical cargo handling machines replacing manual unloading of ships (Van Driel and Schot, 2005), steamships replacing sailing ships (Geels, 2002), jet engines replacing piston engines (Geels, 2006). While normative and cultural changes were often implicated in these transitions, these were not the main drivers.

The issue of directionality, in particular normative orientation, thus forms a new contribution, which has particular relevance for innovation scholars that are interested in transitions to societal goals like sustainability (Elzen et al., 2004). In particular, the article investigates transitions that are initially started by normative contestations from regime outsiders, such as social movements or concerned researchers, who find certain performance aspects of existing regimes normatively unacceptable and in need of change.

The article aims to link the issue of normative orientation to the debate about socio-technical transition pathways. Geels and Schot (2007) analytically distinguished four transition pathways on the basis of differences in timing and kinds of interaction in the multi-level perspective (which looks at interactions between niches, socio-technical regimes and exogenous socio-technical landscape): 1) *transformation*, which consists of endogenous re-orientation of (technological) trajectories in existing regimes; incumbent actors adjust some regime rules in response to external pressures (e.g. from social movements or policy makers); niche-innovations play a limited role; 2) *reconfiguration*, which consists of regime actors adopting certain niche-innovations in response to internal or external pressures; combinations of old and new elements lead to gradual reconfiguration of the system's basic architecture and changes in some guiding principles, beliefs and practices; 3) *substitution*, in which alternative practices or radical niche-innovations replace the existing regime; 4) *de-alignment and re-alignment*, in which the regime rapidly erodes because of major landscape changes; the subsequent emergence of many niche-innovations leads to a period of uncertainty and experimentation. Eventually one option becomes dominant, forming the core of a new regime.

While these transition pathways may be recognized *ex-post* in historical case studies, this is more complicated *ex-ante*, in transitions 'in the making'. In real-time, *multiple* possible transition paths may co-exist and be pursued simultaneously by different actors and social groups. Interactions between actors (including moves and countermoves, strategic games, shifting alliances, learning processes and changing perceptions) then determine which pathway becomes dominant, if any. These interactions are, of course, embedded in and influenced by (gradually) changing contexts. As Abbott (2001, p. 257) argues, 'turning points' and major changes depend on the dynamic interplay between agency and structural 'windows of opportunity':

> "(…) a potential turning point becomes actual only if the action is taken that makes it so. Many potential revolutions fail for want of attempt, just as many attempted revolutions fail for want of structural opportunity. (...) Only after the action has been taken that turns the key can we speak of the turning point as having occurred. It is in this dialogue of structural possibility and action that turning points are defined."

This ontology of dynamic agency-structure interplay implies that process theories should have two complementing components, what Poole and Van de Ven (1989, p. 643) called global and local models:

> "The global (macro, long-run) model depicts the overall course of development of an innovation and its influences, while the local (micro, short-run) model depicts the immediate action processes that create short-run developmental patterns. (...) A global model takes as its unit of analysis the overall trajectories, paths, phases, or stages in the development of an innovation, whereas a local model focuses on the micro ideas, decisions, actions or events of particular developmental episodes."

Building on this distinction, Geels and Schot (2007) characterized the multi-level perspective, on which their transition pathways typology is based, as a global ('outside in') model. With regard to normative contestation, this article aims to develop a local ('inside-out') model of transition pathways. It thus looks at transitions through the lens of 'path creation' as proposed by Garud and Karnøe (2001, p. 3):

> "By stressing path creation, we draw attention to phenomenona in the making, that is, the temporal processes that underlie the constitution of phenomena. Such a perspective assumes reciprocal interactions between economic, technical and institutional forces that constitute technological artefacts and actors involved. Thus,

> social orders, institutional orders and artifacts are both the medium and outcome of human endeavors”

With our research interest in the role of normative drivers in such path creation processes our general research question is: how does normative contestation of existing regimes lead to the enactment of transition pathways? A first hypothesis is that the degree of normative pressure is relevant. Following Abbott (2001), actions and pressure from outsiders ars a necessary but not sufficient condition for wider regime change. Hence, the second hypothesis is that normatively driven regime change depends on windows of opportunity, in particular alignments of normative pressure with other socio-technical developments (e.g. regulations, markets, cultural, technological niche-innovations).This leads us to our specific research question: How does the alignment of increasing normative pressure with other processes lead to the enactment of different transition pathways?

We will introduce insights from social movement theory (SMT) into innovation studies to better understand external normative pressure on existing regimes. Because SMT focuses on political struggles and does not address technology, we complement it with insights on the role of outsiders in innovation (Van de Poel, 2000).

The article is structured as follows. Section 2 conceptualizes normatively driven transition pathways ‘in the making’. Section 3 uses a comparative case study to analyse how normative pressure may lead to the enactment of different transition pathways depending upon the alignment with other processes. Section 4 provides conclusions and discussion.

Concerning our case domain, we analyse how normative concerns about animal welfare have led to innovations in Dutch pig husbandry systems between 1970 and 2008. One case analyzes the sub-sector of dry sows where activists and proponents of change more or less succeeded in achieving the change they wanted. In the other case, that of pig fattening, they did not realise such changes. This comparative study is very suited for our purpose since the normative pressure, at least at first sight, was more or less comparable for both cases.

2. Normatively driven transition pathways 'in the making'

The transition typology by Geels and Schot (2007) starts with a default position of ‘reproduction’, in which regime actors reproduce existing practices and act within relatively stable rule-sets. Refinements and incremental innovation proceed in predictable directions and result in stable trajectories. The stability of existing regimes is the contingent product of interactions between various social groups. Figure 1 gives an impression of the complexity and multiplicity of these interactions.

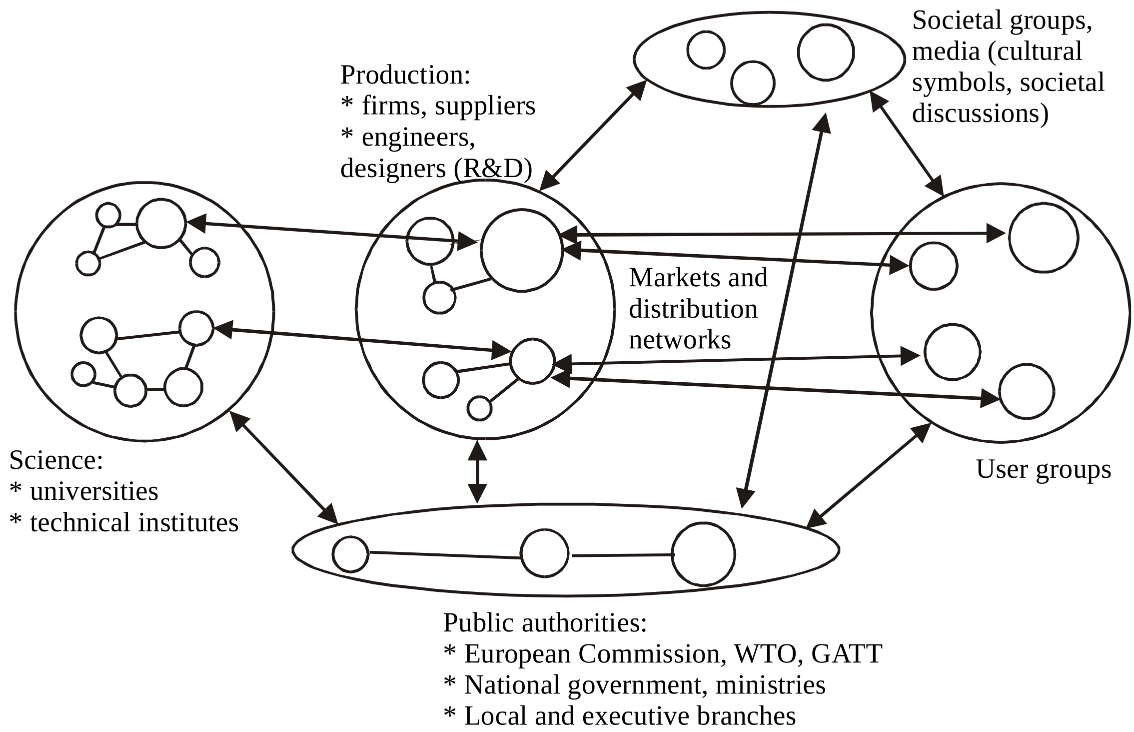

Figure 1: Indication of social groups that reproduce socio-technical systems and enact regime rules (adapted from Geels, 2002, p. 1260)

Incumbent socio-technical (ST) regimes are not necessarily harmonious, homogeneous and fully consensual, but can also contain tensions and conflicts (Greenwood and Hinings, 1996). ST-regimes tend to be characterized by debates and struggles around certain *issues* (Hoffman, 1999).[25] While regime actors may share certain beliefs and principles, these debates also give rise to disagreements and tensions, based on differences in ideas, perceptions, values, and interests. Coherence and tension may thus exist simultaneously in incumbent regimes. Regimes remain stable as long as tendencies towards coherence are stronger than the tensions, i.e. when there is sufficient *congruency* between regime actors (Grin and Van de Graaf, 1996), as a result of actors sufficiently sharing basic regime rules (e.g. guiding principles, beliefs).

Incumbent regimes usually have sufficient congruency because of internally stabilising lock-in mechanisms (e.g. Unruh, 2000), resulting in the default reproduction process. More substantial regime change therefore tends to depend on external pressure (Smith *et al*, 2005). Such external pressure can come from regime outsiders who protest against concrete issues (Van de Poel, 2000), from exogenous landscape developments and from niches, i.e. sites where alternative technologies and practices are developed that deviate in one or more dimensions from the existing regime and therefore do not immediately ‘fit’ (Schot and Geels, 2007). But, as in the case of internal tensions, external pressure will not lead to regime change as long as the tendencies towards coherence are strong, and may actually lead to hardening amongst regime insiders.

[25] While the organization and management literature often uses the term ‘organizational fields’, it refers to the same phenomenon as socio-technical regimes, namely multiple interacting populations.

An initial answer to the research question therefore is that destabilisation of regimes depends on two developments: 1) increasing external pressure on regimes, and 2) decreasing coherence and divergence of socio-technical developments within regimes (e.g. regulations, markets, culture, technology). The remainder of this section further elaborates the first point, focusing particularly on normative pressure. We use the case study to further explore the second point, returning to it in the conclusions.
In normatively-driven transitions, outsiders (such as social movements) tend to be the first to articulate moral concerns about the functioning of existing regimes. Regime insiders usually downplay these concerns, arguing that the problem is 'not proven', 'not caused by us', or 'not that serious'. Alternatively, regime insiders may make minimal adjustments in regime practices to pacify complaints. Overall, the regime thus tends to stay on the 'default' reproduction path.

To escape the reproduction path, the normative pressure needs: 1) to increase and 2) 'spill over' to or become aligned with regulatory, economic, or technological developments. With regard to increasing pressure, social movement theory has converged on distinguishing three main processes: I) framing processes, II) resource mobilization, and III) political opportunity structures (McAdam et al., 1996; Davis et al., 2005). These will be elaborated briefly below.

Ad I) The meaning and salience of 'issues' is influenced by the way they are framed. Through this cognitive-cultural process, social movements aim to influence public opinion and the perception of problems. Benford and Snow (2000) argue that the strength or mobilization potential of frames is influenced by: a) their focus (addressing too many issues dilutes the strength), b) their empirical credibility (perceived fit with ongoing events around the issue), c) their cultural resonance (fit with broader repertoires and discourses), d) their emotional appeal (often through images, metaphors etc.).

Ad II) The mobilization of resources is important for internal development of a social movement and for external influence on other actors (e.g. public opinion, policy makers). Important resources are: money, members, internal and external networks, expertise, credibility, respectability, and contacts. If social movements mobilize more resources, their (normative) appeals gather strength (McCarthy and Zald, 1977).

Ad III) The structure of political opportunities and constraints influence the emergence, legitimacy and development of social movements and, hence, the effectiveness of the pressure they exert. The emphasis on *political* opportunity structures stems from the focus of many scholars on the civil rights movement, anti apartheid movement, labour movement, etc. The recent literature (e.g. Benford and Snow, 2000; Lounsbury et al., 2003) also points to *cultural* opportunities and opportunities that may arise from mood swings in public opinion, shocks and crises.

The normative pressure on regimes increases if these three sub-processes grow stronger and begin to influence public opinion, which, in turn, creates legitimacy pressure on policy makers to recognise the problem and do something.

Because social movement theory originates from political science and sociology, it pays little attention to technology. We therefore complement this literature with the innovation oriented typology by Van de Poel (2000) that distinguishes two additional outsiders groups besides societal pressure groups: 1) engineering and scientific professionals, who possess specialist knowledge. Academic research into the nature and causes of perceived problems may lead to knowledge that creates further pressure on regimes (e.g. by making it more difficult to deny the problem). Researchers may also begin to work on niche-innovations that promise solutions. 2) outside (industrial) firms, who posses finance, managerial, and engineering competence to develop alternative solutions for the problem. If learning processes lead to workable alternatives, pressure on regimes further increases (e.g. by delegitimating delays to address the problem).

We will use these conceptualisations in our case study to analyze how the alignment of normative pressure with regulatory, technological and economic processes may result in various transition pathways. The case study is based on various technical and economic reports from research institutes, sector organizations and the Ministry of Agriculture.[26] These data sources were supplemented with semi-structured interviews, especially to explore the reasons behind various developments described in the reports. These interviews were recorded and transcribed *verbatim*. We interviewed representatives from farmers (LTO), slaughtering industry, Ministry of Agriculture, APS and researchers who have been involved in various developments described. To receive feedback to our initial findings we organised a workshop with sector representatives and agricultural scientists from different disciplines. (See Appendix 1 for names)

3. Animal welfare and innovations for two sub-sectors in the pigs sector

3.1. General regime developments in pig husbandry

Development of a flourishing economic sector

The Dutch system of meat production and consumption experienced rapid growth since the Second World War, especially in the 1970s and 1980s. Figure 2 schematically indicates the increasing number of pigs raised in the Netherlands until 1999. After the year 2000, the number slightly decreased to about 11.5 million in the years 2005-2007 (De Bont and Knijff, 2007, p. 50). In 2004, the self-sufficiency of the Dutch pig sector was 227% meaning that about 56% was exported. (Central Bureau of Statistics website: www.cbs.nl) Most of these where slaughtered in the Dutch slaughtering industry where a concentration took place in the early 2000s. This led to the establishement of the Vion group that held two thirds of the Dutch market by 2007 and became the largest in Europe.

[26] The full name initially was Ministry of Agriculture, Nature Management and Fisheries. Later it became Ministry of Agriculture, Nature and Food Quality, allowing continued use of the same Dutch acronym: LNV. In this article we will refer to it simply as the Ministry of Agriculture.

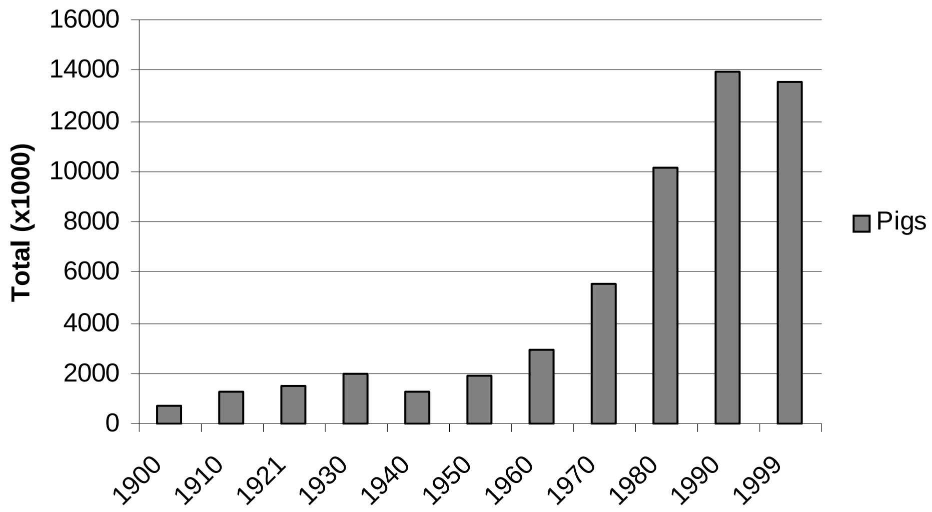

Figure 2: Number of pigs raised in the Netherlands (data from the Central Bureau of Statistics: www.cbs.nl)

This growth was accompanied by a shift towards industrial animal production systems, based on guiding principles such as mechanization, specialization, rationalization and economies of scale. During this shift, pig farming developed into an integrated chain with strong ties between animal food providers, pig farmers, slaughterhouses, supermarkets, and consumers (Geels, 2009). Pig farming itself transformed into a factory-like mass production system, with stables and farms of increasing size. The average number of pigs per farm increased from 25 in 1960 to 1 300 in 2006. (Table 1) The scale increase in pigs per farm was accompanied by a decrease in the number of farms, from about 120 000 in 1960 to 9 040 in 2006 (Table 1), a 92% drop.

	1960	**1970**	**1980**	**1990**	**2000**	**2006**
Number of pigs (million)	3.0	5.5	10.1	13.9	13.1	11.6
Number of farms with pigs	119 469	75 674	44 127	29 210	14 520	9 040
Average number of pigs per farm	25	73	230	480	900	1 300

Table 1: Number of pigs and farms (Groenestein, 2003, De Bont and Knijff, 2007*)*

The sector is thus characterized by a struggle for survival, with strong cost-competition driving further scale increases. Consumers and supermarkets contribute to the strong cost focus in the sector. For supermarkets, meat fulfils the role of *traffic generators*: advertised at low prices, meat should seduce customers to enter their shops, assuming they will also buy other products with larger profit margins. (Hoste et al., 2004, pp. 7-8) This practice creates strong backward pressure from supermarkets to farmers to produce meat as cheaply as possible. Low cost therefore is a guiding principle in pig farming.

Specialization in pig farming has led to two sub-systems: (1) fattening and meat production and (2) breeding, which focuses on sows and piglets. Over the past decades, the Dutch breeding sector has also become an international player, growing from virtually no exports in the mid-1980s to an annual export 4.5 million and 5 million piglets in 2006 and 2007 respectively. (Bolhuis and Wisman, 2008)

Pigs to be fattened were kept in groups of about a dozen in units separated from each other by metal fences with an average floorspace of 0.7 m^2 per pig until 1998. (This was later raised; see below). In their small confinements pigs experienced boredom making them bite the tails of neighbours, resulting in wounds and infection. To reduce this problem, tails were often cut off and teeth commonly clipped. Furthermore, male piglets were castrated (without using aneasthetic) because for boars sex hormones may cause a bad smell when cooking the meat (boar smell). Recent research indicates that the problem is largely overstated and that a testpanel of consumers could not detect the diffence between two samples of boar meat of which, according to a group of experts, one suffered from boar smell. Nevertheless, these images are persistent in the market where certain wholesalers pay less for boar meat and some won't even accept it at all for fear of boar smell. (Backus and Baltussen, 2008)

Dry sows were kept differently because of eating habits. Generally, pigs continue eating when food is available. Mature sows, however, do not grow larger but get fatter. To give them limited rations, sows were kept individually, sometimes in boxes separated from each other. Another option was semi-open stables with fences between the animals in which they were tethered to the floor with either a chain or a belt fixed around the shoulder.

Contestation from outsiders

Since the early 1970s, the shift to industrial mass production methods in pig farming has been accompanied by criticism from special-interest groups that represented new societal values such as animal welfare and the environment. In 1972, the opening of a model pig farm (de Flevohof), intended as the pride of the livestock sector to inform the public about progress in animal husbandry, also invoked strong protest against industrialized living conditions of pigs and gave rise to the creation of an action group 'Sweet Animal' ('Lekker Dier'). The same year, the Foundation for Nature and Environment published a critical report called *Bio Industry* that warned that pigs were no longer seen as living creatures but as resources and input materials for industrial processes. The term 'bio industry' was coined deliberatly to frame the damaging effects of industrial methods on farming. The report also drew attention to stench problems, pollution of water and soil from manure surpluses, and damage to the natural landscape (Crijns, 1998).

The Animal Protection Society (APS; 'Dierenbescherming'), a respectable NGO established in 1864 with over 200 000 members and 70 staff members in the early 2000s, (APS website) also saw industrial animal husbandry as a step backward for animal welfare and favoured keeping animals according to organic principles. In the 1970s, organic pig farming constituted a small market niche of about 1%, carried by small subsection of 'moral consumers' who were willing to pay about 30-40% more for organically produced pork. This meat came from animals that were kept in a more 'natural' environment, had room to play and could exhibit their natural behaviour. This organic niche expanded to about 2% in the early 2000s.

Initially, animal welfare concerns were downplayed and ignored in both sub-sectors (fattening pigs and breeding), causing pig farming to remain on its existing 'reproduction' path. In the late 1990s, however, the sub sector of dry sows, that were initially kept in individual boxes, began moving to group husbandry systems. This entailed the adoption of new technical feeding systems which constituted a 'reconfiguration' path. New national and EU regulations mandate that by 2013 this transformation should be completed for the whole subsector.

In contrast, changes in the fattening pigs sub-sector have been less substantial, consisting mainly of regulatory changes that specify somewhat more space for pigs (from 0.7 m^2 to 0.8 m^2 in the early 2000s) and some other provisions. This difference in outcome is not for lack of efforts, because outsiders have developed a broad variety of alternatives, including moderate reconfigurations of husbandry systems (Hercules stable, Comfort Class stables, Canadian Bedding) as well as radically alternative practices (organic pig farming).

To explain these contrasting paths, we will analyze how social movements increased the normative pressure on both sub-sectors, and how different alignments with regulatory, market, technical and socio-cultural processes led to different outcomes. Subsections 3.2 and 3.3 successively analyze the dry sows and fattening pigs subsectors and their responses to rising animal welfare concerns.

3.2. Animal welfare and innovations in dry sow husbandry systems

Rising expectations on group housing (1980-1990)

In 1973, the Ministry of Agriculture established a commission “Animal husbandry – animal welfare” to investigate how dry sows were kept. In 1975, the committee published a report that concluded that sow husbandry had some weaknesses, which, however, could be remedied with various technical means. (NRLO, 1975) In practice, however, little changed in the following years.

The debate intensified in the early 1980s. In 1982 the APS released a study that was very critial of sow husbandry, focussing on chained sows stating: “The short chain only allows the sow to stand op or lie down. Turning around or walking a few steps is out of the question.” (Dierenbescherming, 1982, 7) The study concluded that the way sows were kept in the Netherlands was ‘completely unacceptable’. (p.41) With various campaigns, the APS tried to generate public awareness. For this they developed a new problem framing using the catchy term ‘chain sow’ for the dry sows that were tethered to the floor. This term and the accompanying images struck an emotional chord in public opinion which felt that these animals deserved better treatment. (Figure 3; Interview Van de Berg)

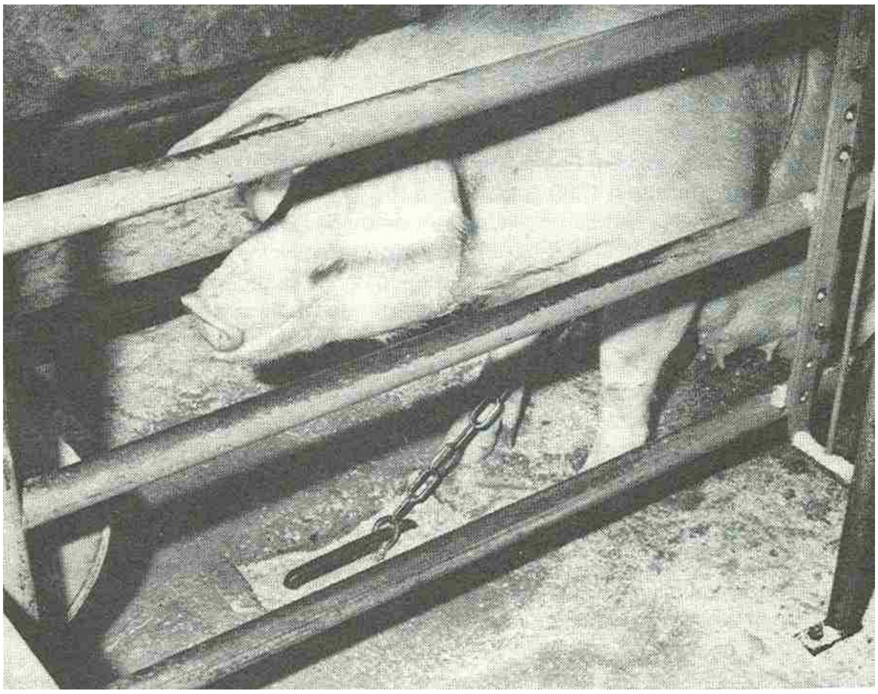
Figure 3: ‘Chain-sow’ (Dierenbescherming 1982, p. 26)

Shortly after the release of the APS report, the Ministry of Agriculture set up a new commission for pig welfare issues. Its 1984 report was also quite critical on sow husbandry. (Commissie Welzijn Varkens 1984) The APS started discussions with the ministry and the pig industry on how to move foreward. In 1986, they came to a joint agreement that individual housing of sows should become forbidden as soon as ‘acceptable systems for grouphousing would be available’. (Dierenbescherming, 1999, p. 21)

To realise this, he ministry started working on future legislation. (Werkgroep Voorlichting Welzijn Varkens, 1988) Furthermore, all research into housing of sows was integrated in a national programme. In the period 1987-1990 a research project was carried out at the Research Institute for Pig Husbandry at Rosmalen, comparing individual systems with a group housing system. For the latter, the main innovation needed would be a system to feed the sows individually. Such a system already existed for cows which was adapted for dry sows. The initial design consisted of an open space where the sows were kept in groups that was connected to an ‘elelctronic sow feeding’ (ESF) station with individual boxes via access gates where each pig was fed a specific ration. After feeding, the sow would have to step out to the shared space and a next one could enter to be fed. Various changes were made to the feeding station in the course of the project. (Bokma, 1990)

During the same period, triggered by the public and political discussion, several farmers agreed that individual sow housing was not very friendly to the animal. In the late 1980s, in parallel to the research programme, some of them started to convert their stables to a Rosmalen-like system. Their numbers grew at a modest rate until a total of several hundred, some 5% of the total, by 1990. (Interview Vermeer)

Stagnation and decline (1990-1997)

Gradually it appeared, in research as well as in practice, that group housing had serious problems. The reason was that the basic design was copied from the cattle sector, without taking into account that pigs behave differently than cows. While cows tend to wait their turn to be fed, sows are prepared to fight for more food and eat as much as they can. If one sow was eating, for instance, a stronger sister bit her in the rear to chase her away and started eating a second ration. Further research would be needed to explore this further. (Backus et al., 1991)

In the early 1990s, several pig-farmers, who had moved to group-housing, shifted back to the individual system. About half of them, however, stuck with the concept. These pig farmers had developed specific farming skills for successfully keeping pigs in groups. (Interview Vermeer)

Scientists at the Rosmalen research institute continued to investigate group housing systems. The fact that some 2% of the farmers had no serious problem with the group housing suggested that the system could work despite its bad image. APS and the scientists also referred to the UK where group-housing was more widely applied and a new bill would enforce it by the end of the decade. In the early 1990s, the scientists occasionally interacted with the ministry and the APS on research findings and on shaping further research. By 1996 they had developed and tested a second generation of group housing systems, exploring different variants.They concluded that group housing was now ready for practical use but that it would require new manegerial skills from the pig farmer. (Backus et al. 1997)

The sector and the ministry, however, showed only lukewarm interest. At the time, there was much more societal concern for disposal of manure and emissions from the bio industry than animal welfare which was rather low on the political and societal agenda. (Interview Vermeer) Thus, in terms of our conceptual vocabulary, the political opportunity structure that had been favourable to group housing in the late 1980s, had disappeared in the mid 1990s.

According to one involved researcher it was almost taboo to talk about group housing in the mid 1990s. In his view this was due to a surplus of eagerness to move to group housing in the 1980s, an eagerness shared by certain pig farmers and the ministry. They used crude concepts adapted from the cattle sector and then found these did not work very well. This eventually led to sector-wide hostility towards group housing of dry sows in general which was impossible to counter with results from further research, no matter how hard the scientist tried to show that the second-generation system worked well. (Interview Swinkels)

Swine-fever and the shift towards reconfiguration (1997-2007)

After 4 February 1997, the polical opportunity structure changed again due to an external shock. The trigger was an outbreak of swine-fever in the Netherlands that spread rapidly. On numerous pig farms, all pigs were killed and cranes were used to load dead pigs onto huge trucks to take them to destroyers. These scenes were broadcasted widely on television and stimulated a lively societal debate. In total, over 11 million pigs were killed including almost 3 million 3-17 day old piglets. (Ministry of Agriculture data, cited in Dierenbescherming, 1999, 47) Many, including politicians as well as the public, felt something really had to change in the system of animal husbandry.

Within a few months, new legislation was drafted and adopted that would make group-housing compulsory in ten years, i.e. in 2008. The sector protested heavily but did not stand a chance against the societal and political pressure and determination. LTO, the sector representative, realised that it made no sense to fight this change further and that it had to find ways to inform farmers on how to make a smooth transition. They organised meetings with pig-farmers throughout the country at which the Rosmalen researchers were often invited to inform the attendees of their findings. The unrest lasted about half a year and then gradually disappeared. (Interview Vermeer)

Market forces also played a role in the change towards group housing. The crucial economic factor was the export of Dutch pork to the UK. As of 1 January 1999, dry sows in the UK would have to be kept in groups. UK pig producers, animal welfare and consumer organisations put pressure on the British retailers to sell only bacon and other pig meat that would be produced in production chains with group housing facilities for dry sows. They were successful and because the UK formed a large export market for the Dutch slaughter industry they got an interest in ensuring that a significant share of Dutch dry sows would be kept in groups. (Vermeer et al., 1999) This made Dumeco, then a major slaughter company that later became part of the Vion group, give a bonus to farmers who kept dry sows in groups. (Interview Swinkels) Thus, the normatively driven innovation in the niche aligned with market developments in the regime.

Also at the European level, pig husbandry became an increases matter of concern. The European Commission enacted new regulations that resembled the Dutch although they lagged a few years. New EU regulation forbade keeping dry sows on chains as of 2005 (2001 in the Netherlands) and by 2013 all dry sows in the EU should be kept in groups. The Dutch pig sector argued that this meant unfair competition as for them group housing was compulsory by 2008 and to comply, the date has been changed to 2013 in the Netherlands as well. (Enting, et al., 2006)

3.3. Animal welfare and innovations in pig fattening husbandry systems

Downplaying criticism; low animal welfare interest (1970-1997)

In the early 1970s, animal welfare groups criticized pig fattening husbandry systems of on a range of issues:

- Keeping large numbers of pigs in small units;
- Not allowing pigs to go outside;
- Bare, concrete floors where pigs could not root;
- Cutting tails and teeth;
- Castration without using anaesthetic;
- General aversion towards the bio industry (treating animals as commodities rather than living beings).

Responses from the sector claimed either that problems were not that bad or that economic pressures made it impossible to change. For instance, letting pigs outside would make them more susceptible to diseases and make the controlled disposal of manure, urine and atmospheric emissions problematic. Covering the floor with straw would also worsen the manure problem and make cleaning more difficult.

For the Dutch government, economic considerations prevailed over animal welfare concerns. Internal criticisms were silenced by the Ministry. In 1972, one researcher at the Institute for Animal Husbandry Research wrote a report that noted that pigs were biting each other’s tails and ears because of boredom and stress, related to confinement in small spaces. The Ministry stopped publication of the report and forbade the author to speak about it in public. (Crijns, 1998)

Animal welfare received little political and social attention in the 1980s and early 1990s, because the agenda was dominated by exacerbating manure problems. In 1984, stench and water pollution problems were visible, smellable, and pressing. That year, the CBS (Central Bureau of Statistics) published a manure report that the

Ministry of Agriculture had tried to hold back for many years. (Frouws, 1994) This report crystallized societal frustration and led to high political pressure for change in relation to environmental issues.

Animal welfare concerns, however, such as stress from overcrowded stables, were placed on the backburner. An EU-directive specified an average space of 0.65 m^2 per pig, just enough for a 110 kg pig to lay down. The Dutch standard was slightly better, namely 0.7 m^2 per pig. This did not damage Dutch competitiveness because, as experience indicated, pigs do not grow well if they have too little space. (Interview ten Have) The APS frequently argued for further increases of floor space to enhance animal welfare. The sector representative LTO opposed this, arguing that additional costs would undermine the Dutch export position and the Dutch ministry concurred.

Renewed contestation and gradual transformation (1997-2000)

After the 1997 swine fever outbreak, NGO and public protest against the bio industry intensified. The same year, two new NGOs emerged with a more radical agenda than the APS, notably Awake Animal ('Wakker Dier') and Pigs in Despair ('Varkens in Nood'). Both groups sought to end the bio industry altogether.

In this context, animal welfare concerns rose rapidly on the public and political agenda. This societal pressure 'to do something' and the political determination to be strict, led to tightening rules, which constituted a gradual regime transformation path. Although economic considerations remained prominent for the government, more attention was given to animal welfare issues.

To understand the discussion on regulations it is relevant to know that many laws and regulations in the pig sector are communal, meaning that regulation is laid down in directives of the EU. Member states have to translate these into national legal and administrative measures. In relation to pig welfare, the relevant EU directive is 91/630/EEC that specifies a minimum floorspace of 0.65 m^2 per pig. (Enting et al., 2006)

Since 1994, the Netherlands had specified a somewhat stricter rule, notably demanding 0.7 m^2 per pig. Furthermore, the Dutch ruling ('Varkensbesluit') specified that in due course it would be forbidden to keep pigs on floors that were 100% slatted (to collect manure and urine in underlying cellars). For new stables, 0.3 m^2 per pig would have to be solid and by 2003 fully slatted floors would be prohibited. (Spoolder et al., 2003). The EU directive does not have such a provision.

Shortly after the outbreak of swine fever the Dutch government decided that in 1998 the floorspace standard would be raised to 1 m^2 and that by the year 2000 the mandated solid floor area would be 0.6 m^2. (LNV 1999) The sector protested heavily as this implied they could keep 35% fewer pigs in the same area as their European competitors. The Dutch government conceded and the rules were somewhat relaxed. As of 2008, new stables would have to provide 0.8 m^2 per pig which would become 1 m^2 by 2013 with the solid area having to increase to 0.4 m^2. (Enting et al., 2006) Another new rule, specified in the EU directive, was that as of of 1 January 2003 pigs should have permanent access to a sufficient quantity of material "to enable proper investigation and manipulation activities, such as straw, hay, wood, sawdust, mushroom compost, peat or a mixture of such." (Enting et al., 2006) As stated, member countries had to make their own interpretations of these directives and the Dutch ruling was far less precise. The typical solution in the Netherlands was to hang a chain in the sty that pigs could bite in and pull on which was allowed by the Dutch regulation. (Interviews Van de Berg, De Greef)

Pig farmers were anything but happy with the new regulations, especially the 2013 rule of 1 m^2 per pig. They argued that this would undermine their competitive position in the international market. Going from the minimum of 0.7 m^2 for existing stables to 1 m^2 was expected to cost € 75 per pig-place which added 2.8 eurocents per kilogram to the price of meat. Because this was more or less the profit farmers made, this was not considered economically viable. (Interviews Ten Have, Swinkels)

Further contestation and attempts at reconfiguration

A concentration of animal diseases in the late 1990s and early 2000s (swine fever, BSE, foot and mouth disease, bird flu) further deteriorated the public image of industrial animal production. In 2002 it led to a new political party that exclusively focussed on animals. This Party for the Animals ('Partij voor de Dieren') participated in the 2003 general elections but won no seats. In 2006, they were more successful, gaining 2 parliamentary seats out of 150. They were supported by a wide variety of public figures including authors, artists and TV personalities. This strategy of network building increased their visibility and legitimacy, and enabled them to influence public debate.

Since 2006, the party has bombarded the ministry with parliamentary questions on all sorts of issues relating to animal welfare. (cf. website www.partijvoordedieren.nl) Their visibility also required other political parties and the Minister of Agriculture to become more outspoken on animal welfare issues. In 2007, animal welfare issues also received more attention at the European level, leading to debates about raising the EU floor space standard from 0.65 m^2 to about 0.75 m^2 by 2013. (Interview Ten Have) Thus, a new political opportunity structure developed for animal welfare issues and innovations.

In response to these new social and political pressures, the pig sector set up image campaigns like 'Pigs in Sight' ('Varkens in Zicht'). Some pig farms were equipped with sky boxes where the public could watch the stables and behaviour of pigs. This campaign was intended to convince the public that pigs were treated well and that there was no reason for change. (Interviews Swinkels, Van de Greef)

While political actors and pig farmers focused on framing processes and regulations, which mainly led to transformation paths, outside actors worked on innovations that might contribute to more substantial reconfiguration paths. These innovations involved new components and husbandry systems (mainly developed by engineers and scientists in various research institutes) and new market segments (mainly developed by new retailers) that will be discussed in the following sections.

Alignment with technical development: alternative pig husbandry concepts

Some alternative stable concepts such as 'Canadian Bedding' (see further below) were modifications of mainstream concepts but first we will discuss two more radical concepts, notably the Hercules stable and Pigs in Comfort Class.

Hercules stable

WUR scientists, outsiders in our analytical framework, started the Hercules project in 1998. Their approach was based on the expectation that emission legislation would be tightened in the future. Furthermore, after the 1997 outbreak of swine-fever, tighter animal welfare rules would also require new husbandry concepts. (Ogink et al., 2001)

Processing of manure became a focal point in the design and communication on the Hercules[27] project. In a conventional pig stable, most of the floor space is slatted. Manure and urine fall on the floor and are pressed through it by the pigs walking around. It is collected in underground cellars from which it is retrieved to be disposed of. Because of the large slatted area it is problematic to use straw since that will clog up the openings. For animal welfare reasons, the government intended to increase in the solid floor area which farmers were not happy with. The larger the solid area the more effort they would have to put in cleaning the floor.

One of the focal points in Hercules was to design a system for separation of manure and urine. The technical approach was to develop a slightly convex moving manure belt under a row of pigpens. The liquid fraction (the urine) would drip of from the sides and was collected underneath while the solid fraction (the manure) was collected at the end of the belt in a concentrated form. (Ogink et al., 2001)

There were several societal advantages to this system. Firstly, the early separation of solid and liquid fractions led to a significantly lower production of ammonia. Furthermore, this separation was an important first step in the separation of minerals since the liquid fraction (the urine) hardly contained phosphor. There were also animal welfare benefits. In view of costs, this moving belt could not be too wide implying that the slatted part of the pigpen where pigs should relieve themselves should also be smaller. This had the advantage that there was more solid floor space. The concept provided 1 m^2 of floor space per pig (25% more than the regulated standard) of which 75 % was solid. This floor could be cooled or warmed by running either cold or warm water through hoses in the floor. An increased area of solid floor could also be better combined with the use of straw which had become an icon in animal welfare. Pigs like to play with straw, chew on it and root in it. Part of the Hercules design was a device called the 'straw swing'. Pigs could play with it with their snout for which they were rewarded with some straw. Because of these provisions the Hercules concept was expected to be some 5-10 % more expensive than a conventional stable. After some years of research and development the ensuing Hercules system was considered "complex but feasible". (Van den Top et al., 2005)
The business studies school from WUR explored the market introduction of Hercules. In parallel with the technical research they carried out surveys among pig farmers to assess their judgement. These farmers were quite positive about the reduction of emissions and the processing of manure. They also thought the concept was close to what consumers desired but had serious doubts about energy use (the concept used various active systems that consumed energy) and economic profitability. (Joldersma, 2003)

By 2005, when the technical research was finished, the world of pig farming had changed significantly compared to the 1990s. Although animal welfare and environmental concerns were still clearly present in the societal and political debate, they were less prominent. The sense of urgency that had followed the 1997 outbreak of swine fever and other animal deseases had lagely disappeared. In 2003, a new government had taken office that strongly emphasised deregulation. So, when the Hercules concept was considered ready for practical use, the aligment between the political process and normative pressure had weakened considerably. As a result, the project results were shelved.[28]

[27] Named after the Greek hero who was awarded the devine status for his heroic deeds one of which was to change the course of two rivers to clean the king's pig stables. For a detailed description and analysis of the Hercules project see Bos and Grin 2008.
[28] More precisely, Bos and Grin (2008) have identified five factors why it didn't take off.

Pigs in Comfort Class

The ‘Pigs in Comfort Class’ approach was also an example of normative pressure aligning with technical development. In the year 2000, the APS proposed an activity on ‘animal centred design’ to the Ministry of Agriculture within its long-term programme on ‘Animal Production 2030’. The ministry agreed and a desk study was started by APS and WUR-researchers (another group than the one working on Hercules) to explore this. They took pig husbandry as an example to elaborate the methodology. The methodology started by identifying ten basic needs of pigs that were translated into various technical solutions which, together, defined the stable concept. The main conclusion of the study was that it was possible to take animal welfare as a starting point to design stables and that it could be assumed that in such stables animals could also be kept in an economically viable way. APS proposed to LTO that they could try to build such a stable together, to prove that it could indeed be done. LTO, feeling the societal pressure to develop new forms of husbandry, accepted. (Interviews Ten Have and Van de Berg)

Although they agreed on building the stable there were differences in the visions of the partners. LTO saw the project primarily as a research project that might have an impact in the long term. APS, however, aimed for a stable that could operate within the existing system and be economically viable (Interviews Ten Have and Van de Berg). Eventually, a compromise was developed between aiming for the long and the short term. First, a demonstration stable would be built to demonstrate the technical viability. Then pigs would be introduced to demonstrate that they were actually better of in the new stable. After that, five pig farmers would be sought to use the new design principles in their own stable and demonstrate the economic viability. Thus, it was not only a research project but it would also have to operate in practice. (LTO and Diernebescherming, 2006)

This eventually led to the development of a new stable concept called Pigs in Comfort Class (PCC) with a term derived from the aviation sector. Regular stables were basically designed according to economic criteria, housing pigs in ‘economy class’. In contrast, the new stables were called ‘comfort class’, because pigs were much better off. (Interview Van de Berg)

The PCC-approach specifies the 10 basic needs of pigs, but it does not prescribe technical solutions to satisfy these needs. (LTO and Dierenbescherming 2006, 4) To give an example, in a popular vision pigs have a need to be outside and roll in the mud, allegedly because they are dirty animals. The PCC approach, however, looks at the reasons behind this behaviour. Pigs do not roll in the mud because they are intrinsically dirty but because it serves two very useful functions for them: it helps them to cool down when it is warm and it frees them from skin-bugs which they pick up walking around. Cooling down can also be realised by other means, e.g. by cool air, a cooled floor or an occasional cold shower. When kept indoors, pigs are hardly pestered by skin-bugs. So the need specified is the need to cool down when it’s hot and there can be various technical solutions to satisfy this need. (Interview de Greef)

In Raalte, in the province of Overijssel, the demonstration stable was built in 2006. The specification of needs resulted in a floor space of 2.4 m^2 per pig, three times the regulated standard. WUR animal scientists considered this area necessary to provide pigs with various function areas for eating, sleeping, playing and relieving themselves. (De Lauwere and Luttik 2006) LTO was convinced that the large floor space could not be upheld in practice on economic grounds but it wanted to stretch the design for the demonstration project to assess what this might lead to. (Inteview Ten Have)

The next step would be to gradually strip the design of some of its features until a concept would be reached that was considered economically viable. The first results indicated that this was possible at least in some respects as pigs tend to mix function areas and would therefore need less space. (Interview Ten Have)
Mid 2007, five farmers were chosen who would implement the PCC concept in their own stables and receive a subsidy for the extra cost they would have to make. They did not build new stables but refurnished some units (rather than the whole stable). Following the PCC philosophy of specifying needs rather than solutions these farmers applied various techniques to satisfy the needs. Some chose a bedding stable, another applied natural ventilation, again another just used a conventional stable and made a few small modifications. Strikingly, none of them implemented anything near the 2.4 m^2 per pig considered necessary by the scientists and that was used in the Raalte demonstration stable. (Interviews Van de Berg and Ten Have)

Alignment with market developments
The Dutch Ministry of Agriculture has high expectations of the PCC concept. Late 2007, the Minister of Agriculture published a white paper on animal welfare which set the goal for 2011 that 5% of the animals should be kept in 'integrally sustainable' husbandry systems. (LNV 2007, p. 5) It was not specified what this meant but for pigs the solution favoured by the ministry was to follow the Pigs in Comfort Class approach. (Interview Steegmann) The white paper indicates that this should not be achieved via regulation but via interactive processes with participation from all relevant stakeholders in combination with market processes. But it remained unclear how the take-up of this concept would occur in a sector where economic considerations thus far constituted an insurmountable barrier. One concrete approach focused on consumers. Via various communication campaigns (one using bilboard posters stating: "The animal cannot choose. You can!") an appeal was made to the consciousness of consumers to pay more for alternatively produced meat, targetting a gradual transformation of the regime. Thus, the ministry aimed for an alignment of the normative pressure with technological and market developments.

The major stumbling block for new husbandry systems is that they raise the price of fattening pigs in a market that is extremely competitive. As an extra barrier, especially the slaughtering industry stresses that the fact that only 40% of the pig is sold as fresh meat creates an additional obstacle. The remainder goes into a wide array of processed products - sausages, ingredients for other meal products (e.g. soups), pet food, gelatine, cosmetics, etc. (Hoste et al. 2004, 19-23) These have to compete with comparable products from often unknown origins offered at bottom prices. As a result, the additional costs made can only be recovered via the 40% of fresh meat which would then have to be disproportionally raised in price. (Interview Jansen)

An alternative market segment is the organic niche with far stricter regulations for raising animals. The chain is largely separated from the industrial animal production sector with specialised slaughterhouses, organic shops and some local markets. In 1999, 22 parties in the organic pig sector concluded a covenant for an upscaling of the organic sector. This included Albert Heijn, the largest supermarket chain in the Netherlands, but sales in the early 2000s were disappointing, causing Albert Heijn to loose a lot of money and drop its leading role. Pork in this sector is about 40% more expensive than regular and currently has about 2% of the overall market. Actors in this niche are very outspoken that they want all animals to be kept according to organic principles and therefore aim for a substitution of the existing regime but the expansion stagnated in the early 2000s. (Meeusen et al. 2005, 127-143)

Although the APS favours organic husbandry, it also seeks to improve the situation in the industrial animal production sector. Attempting to find a compromise that many in the organic niche would abhor it has worked with a relatively new Dutch retailer, Jumbo supermarkets. Jumbo is family owned company, a relative outsider in the supermarket world that seeks to profile itself with low prices and care for quality and sustainability. On its website, Jumbo has several pages addressing "responsible food" which also provides information on how animals are kept for some of its 'responsible' products and contrast this with the bio-industy.[29]

One example is that Jumbo sells a special type of pork, next to regular pork, that comes from pigs that are kept in so-called Canadian Bedding stables. This concept was developed in the Vancouver area in western Canada where there are huge forests and a large lumber industry. This industry produces a lot of sawdust that local pig farmers use as a bedding in their stables. This is soft for pigs to lie on and gives them something to root in and chew on. This concept has also been adopted by a small number of Dutch pig farmers. Jumbo has embraced the concept and now sells meat from pigs from one farmer who houses pigs in these stables, calling it "Jumbo conscious pork". APS has designed a special quality label that Jumbo is allowed to use. This meat is about 15% more expensive than typical supermarket pork. In 2006, Jumbo started to sell it in six of its shops but in 2007 extended this to all of its over 100 outlets.[30] (Interview Van de Berg)

This Jumbo conscious pork is an example of what is called an 'intermediary market-product', i.e. between organic and regular pork. Meat in the intermediary segment comes from pigs that are kept under specified better circumstances than in the mainstream and as a result this meat would be slightly more expensive. One of APS's strategies is to expand this segment. (Interview Van de Berg) The Dutch Ministry of Agriculture sees such an intermediary segment as an important lever that could help the PCC concept break through. (Interview Steegmann) In accordance with the emphasis on deregulation since the early 2000s, the government expects that an alignment of normative pressure with market end technological pressures should suffice to embark on a reconfiguration path for pig husbandry.

4. Conclusions

The research question was: How does the alignment of increasing normative pressure with other processes lead to the enactment of different transitions pathways? We can now answer this question for the two empirical cases, explaining the different outcomes with the conceptualizations from section 2.

In the case of dry sows, normative contestations from NGOs and animal scientists reached their aspired goals because the 'chain sow' is now forbidden and the practice of keeping dry sows in groups will be legally enforced as of 2013. In the case of fattening pigs, normative contestations had less success, leading to gradual changes in floor space (from 0.7 m^2 per pig via 0.8 m^2 for new stables as of 2008 and 1 m^2 in

[29] http://www.jumbosupermarkten.nl/page/page.aspx?ItemId=2639

[30] A brief history of this episode and the APS involvement can be found at the APS website: http://www.dierenbescherming.nl/dier-en-welzijn/bio-industrie/varkens/jumbo-bewust-varkensvlees Jumbo's perspective can be found at the website in the preceding note.

2013), a slight increase in solid floor space in 2013 and the provision of toys. Various alternative husbandry concepts were developed but did not diffuse widely.

To explain these differences, we will look at two main processes: a) increasing normative pressure, and b) alignments with or spillovers to economic, regulatory, socio-cultural and technological niche developments. To analyze normative pressure, section 2 proposed the concepts of: 1) resource mobilization, 2) (political) opportunity structures, and 3) framing, which was sub-divided into focus, empirical credibility, cultural resonance and emotional appeal. Let us address these issues in turn.

Ad 1) Resource mobilization occurred more or less similarly in both cases, so can not explain the difference. In both cases, the Animal Protection Society (APS) sought to mobilise public opinion and exert political pressure. It interacted frequently with policy-makers and sector representatives, stressing that animal welfare required a change of husbandry concepts. Networks between social movements and (outsider) animal scientists were also present in both cases, with the scientists voicing criticisms and developing alternatives. In the fattening pigs case, APS performed additional work by teaming up with LTO, the (pig-) farmers representative, to demonstrate an alternative concept (PCC). So far, this had relatively little effect on wider diffusion.

Ad 2) Political opportunity structures were also more or less the same for both cases. The shock of the swine fever outbreak in 1997, which produced television images of massive numbers of dead pigs being loaded onto trucks with cranes, provided a window of opportunity in both cases. While alternatives in sow husbandry *did* take advantage of this window, this did not happen for fattening pigs. This not only shows that shocks are *not* sufficient to produce wider change, but also that *timing* and alignment with other processes are crucial (see below). The emergence of the Party for the Animals in the early 2000s was another change in political opportunity structures that similarly affected both cases and increased the political salience of animal welfare concerns.

Ad 3) Framing processes differed considerably for both cases. Firstly, the framing had more *focus* for dry sows, both in terms of problems (the 'chain sow') and solutions (keeping dry sows in groups). For fattening pigs, the framing was less focused, because a wide variety of animal welfare problems struggled for attention. Furthermore, animal welfare problems competed with sustainability issues related to emissions (ammonia) and manure disposal. This multitude of problems led to variety in the niche of alternative husbandry concepts, e.g. the Hercules stable, Pigs in Comfort Class, Canadian Bedding. The variety of problems and solutions for fattening pigs limited the focus and strength of framing processes for this case.

Secondly, framing processes had stronger *emotional appeal* for dry sows, especially through the catchy term of 'chain sows'. The public, policy makers and even some farmers agreed that a sow with a chain or belt around the shoulder was unfriendly to the animal. The APS used this powerful image to articulate a moral framing of unacceptability. The alternative (group housing) was also well framed by linking it with notions of pigs as sociable animals. For fattening pigs, in contrast, the framing was less successful in terms of emotional appeal. Furthermore, the pig farmers, especially their representative LTO, were more successful in *counter-framing* for fattening pigs than for dry sows. For fattening pigs, the farmers argued that strong international cost-based competition prevented them from adopting the more substantial animal welfare innovations that would raise costs and reduce competitiveness. Initially, in the early 1990s, a counter-framing strategy also worked successfully for dry sows ("experience shows pigs in groups is a disaster") even though proponents pointed to 2% of the sow farmer's population who had successfully implemented the alternative in practice.

This latter counter-framing lost its strength when the general problem framing gained *empirical credibility* and *cultural resonance* through the swine fever outbreak in 1997. Other animal diseases and food scandals in the late 1990s further strengthened general concerns about intensive animal production mobilising public opinion as an additional resource to put pressure on political and regulatory processes. Even though swine fever was not directly linked to animal welfare problems, the crisis resonated with the general idea that 'something was wrong' in pig farming practices and thus strengthened the general problem framing. However, this general framing applied both to dry sows and fattening pigs, and thus does not explain the different outcomes.

The conclusion from this analysis is that normative pressure for dry sows was stronger than for fattening pigs, mainly because of differences in framing. While resource mobilization and political opportunity structures also increased the normative pressure, they did so more or less equally for both cases.

However, the increasing normative pressure, which spilled over to public opinion and created credibility pressures on policy makers, is only one part of the explanation. For the other part, we will return to the second part of our research question which concerns the degree of alignment of normative pressure with economic, regulatory, socio-cultural and technical developments and how different combinations may induce particular transition pathways.

The shift to group housing for dry sows constituted a *reconfiguration* path, because it entailed a change in practices - the management of sows required farmers to develop some new routines, which many of them initially resisted - as well as development and adoption of new technical components (especially new feeding systems that separated eating sows from each other). Thus, *technological change* was important, especially technical improvements and stabilization in the shift from first generation (late 1980s) to second generation (mid-1990s). The technology experienced a hype-disappointment cycle, with farmers having high expectations in the late 1980s, causing about 5% of sow farmers to shift to group housing. Teething problems with the first generation feeding systems led to disappointments, however, causing a decline in group farming to about 2%. When second generation components were developed, negative perceptions of group housing had hardened, which frustrated further diffusion. The swine fever shock in 1997, however, provided a window of opportunity, which group housing took advantage off. Spillovers to public opinion led to credibility pressure on policy makers, who were expected to do something. Policy makers then issued *strong regulations* that made it compulsory in 10 years time. Farmers protested, arguing that this was not possible and would reduce competitiveness (counter-framing) but NGOs and policy makers could overrule these protests, pointing both to technical progress (second generation) and the 2% of farmers who showed that such concepts could be applied successfully. Also *market forces* played a role, especially from UK supermarkets (which faced more radical animal rights groups) who in 1999 demanded group housing in relation to imported bacon. Alignments with technical, market and regulatory processes thus helped the normative pressures to have an effect on sow husbandry. This alignment of varying pressures is summarised in Table 2.

An additional conclusion from this case is that not just the *degree* of alignment is important, but also the *timing*. It was particularly crucial that the technical alternatives were sufficiently developed when the window of opportunity opened (due to the 1997 swine fever shock) and that proponents could point to some degree of practical experience (the 2% of farmers who demonstrated economic feasibility). Both aspects enabled policy makers to issue strict regulations that helped push the alternative through.

For fattening pigs, the proponents of alternatives such as Hercules, Pigs in Comfort Class (PCC) and Canadian Bedding targetted a reconfiguration path. *Technical change* for these alternatives was substantial and culminated in stabilized concepts in the early 2000s. At the time of the 1997 crisis, however, this was not the case as most innovation efforts in the 1980s had focused on manure problems rather than animal welfare. So there were no well-developed and stabilized alternatives to take advantage of the 1997 window of opportunity. By 2005, when the Hercules project was finished the political interest had gone and the concept was shelved. Two years later, with the upcoming of the Party for the Animals the interest rose again and the PCC concept, that was then in the middle of its development, gained a far better reception, thus reinforcing the conclusion about the importance of timing.

Furthermore, *regulatory pressure* was weak or absent in this case, partly because there were no available alternatives that could be pushed through, and partly because the counter-framing strategies of farmers (alternatives would reduce competitiveness) were more successful. *Market demand* was also weaker in this case, with mainstream consumers not translating moral concerns into purchasing decisions, buying instead the cheapest meat in supermarkets. Recent attempts by a Jumbo, a relative outsider in the supermarket sector, to create an intermediary animal friendly segment (between organic and regular pork) are interesting in this respect, but have not yet produced major successes. In sum, while these alternatives constitute reconfiguration paths ‘in the making’, the lack of alignment with regulatory and market processes has been hindering broader diffusion.

The historically dominant path in the fattening pig sub-system has been gradual transformation, driven primarily by somewhat stricter regulations in response to normative pressure and public concerns. Following the 1997 crisis, and in response to the accompanying public outrage, government regulations mandated increased floor space from 0.7 m^2 to 0.8 m^2 per pig for new stables which will increase to 1 m^2 by 2013. Later regulations also specified the introduction of toys in stables.

Although this appears like a transformation path we should be careful with this qualification. For outsiders, the shift from 0.8 m^2 to 1 m^2 per pig by 2013 constitutes a marginal change that leaves the basic practice untouched. In their view, this change constitutes reproduction, not transformation of the practice. Farmers, by contrast, see the enlargement as a major change because they can hold 25% fewer animals in the same area which puts pressure on the whole chain for changes which may lead to more substantial changes later on. This points to a fundamental problem for analyzing transitions ‘in the making’. The concept of ‘transition’ points to a notion of substantial change, which involves some assessment of depth, scope, radicality of change. While such assessments often can be made for historical cases, this is more difficult for ongoing transitions ‘in the making’ where different actors may have different views, as this example indicates. The categorization of empirical cases in terms of analytical transition pathways may thus be difficult and contested.

In contrast to the dominant transformation path, the radical alternative of the organic niche can ben seen as the enactment of a substitution path, at least in the intentions from proponents. Despite its 40% higher price its market share grew from 1 to 2% between the 1970s and early 2000s. Still, it remained a small market niche, mainly sold via specialised retail outlets that are not visited or even known by ‘average’ consumers. This niche has hardly any influence on the wider pig sector. Expansion of the niche would require substantial socio-cultural shifts and changes in consumer habits and preferences for which there currently no indications.

For different aspects and episodes of the two cases, Table 2 summarises the degrees of pressure for animal welfare change on different dimensions. Normative pressure from outsiders was present throughout, although with different strength for the cases and periods. The influence on regime change, however, depends on alignments with pressure for change on other socio-technical dimensions, notably regulatory, market and technology. The table also shows how different degrees of alignment result in different onsets of analytical transition pathways. Neither case followed the ‘de-alignment and re-alignment’ pathway which is therefore absent in the table.[31]

	Normative	Regulatory	Market	Technology	**Transition pathway**
Dry sows regime (before 1990)	+	+	0	+	Transformation (reconfiguration in niche)
Dry sows regime (1990-1997)	+	0	0	+	Transformation (reconfiguration in niche)
Dry sows regime (after 1997): Group housing	++	++	+	+	Reconfiguration
Fattening pigs regime (before 1997)	+	0	0	0	Reproduction
Fattening pigs regime (after 1997): toys and somewhat larger stables	+	0/+	0	0	Reproduction; some groups target transformation
Fattening pigs niches (2000s): Hercules stable, Pigs in Comfort Class, Canadian bedding	++	0	0	+	Reconfiguration (no wider diffusion as yet)
Intermediary market segment niche (Jumbo)	+	0	0/+	+	Reconfiguration (no wider diffusion as yet)
Organic farming market niche	+	0	0/+	+	Substitution (no wider diffusion as yet)

Table 2: Degrees of pressure for animal welfare change on different socio-technical dimensions, and the resulting transition (0 = absent; 0/+ = small; + = moderate; ++ = strong)

[31] De-alignment and realignment is probably a rare pattern, as it requires large and relatively rapid landscape changes (Geels and Schot, 2007).

Onsets of different pathways co-exist during transitions 'in the making', both in empirical substance and analytical conceptualization. While some paths are more dominant than others, the future is fundamentally open in the sense that actors may change their perceptions, goals, and strategies, depending on social interactions and the alignment with cultural, economic, political and technical change. With regard to directionality and normative contestation in transitions, the article has not only highlighted an important and interesting new topic, but also related conceptual ideas and debates in new ways. Normatively driven transitions start with pressure from regime outsiders, which we further operationalized in terms of resource mobilization, (political) opportunity structures, and framing processes. This normative pressure in relation to animal welfare in one case was succesful in instigating a move away from the default reproduction path of the existing regime whereas in another case this did not happen. The difference can be explained by looking at alignments of normative pressure with regulatory, market, and technological niche developments. The *degree* of these alignments and their *timing* then determine if regime change follows a transformation, reconfiguration or substitution path.

This article has wider relevance for the field of innovation studies, to which evolutionary economics has made important contributions. While we now know much about factors that influence general innovativeness (often related to economic issues of competitiveness and profitability) and the speed of technical trajectories, questions surrounding directionality and normativity are underdeveloped. As Von Tunzelmann et al. (2008) conclude in a review article on (changes in) technological paradigms:

> "Evolutionary economists will have to start to address such questions if they are to provide a more realistic view of the world. They highlight the underdeveloped normative and political implications that have, as of yet, not properly been developed" (p. 479).

This article has addressed these questions with a conceptual framework and comparative case study. To generalise the findings, we hope that other studies will further investigate the topics of directionality and normative orientation, not only in transitions, but also more generally in innovation studies. The article also addressed another research challenge identified by Von Tunzelmann et al. (2008):

> "Finding paradigms after they have become established seems to be reasonably easy. But how to catch them as they form, and manage the formation and establishment of new ones, remain very poorly understood and under researched" (p. 282)

Our analysis of 'transitions in the making' has shown that these dynamics are contested and complex, because of multiple co-existing options the fate of which depends partly on (strategic) agency and partly on structural windows of opportunity and alignments with other ongoing processes. Thus, the framework presented and explored in this article lays the foundation for interesting further research on normatively driven innovations that is both analytically interesting and societally relevant.

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information they provided and the workshop participants for the feedback to our initial findings. (See appendix for names)

Appendix

Interviewees

Bert van de Berg, Animal Protection Fund
Bram Bos, WUR-Animal Sciences Group
Karel de Greef, WUR-Animal Sciences Group involved in PCC
Annechien ten Have, LTO
Paul Jansen, Vion (largest European slaughter company)
Celia Steegmann, Ministry of Agriculture
Han Swinkels, LTO; former researcher who worked on group housing systems
Herman Vermeer, WUR-Animal Sciences Group who worked on group housing systems

Participants workshop

We also organised a small workshop to receive feedback to our initial findings with the people below who were partly sector representatives and partly scientists from different disciplines. The participants were:

Yvonne Cuypers, WUR-Animal Sciences Group
Karel de Greef, WUR-Animal Sciences Group
Robert Hoste, WUR-Agricultural Economics Research Institute LEI
Woody Maijers, AKK (Agro-chain knowledge)
Jan Merks, Institute for pig genetics
Onno Omta, WUR-Business Administration
The authors of this paper

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[32] This Dutch term is a play of words. ‘Welzijn’ means welfare, ‘wel’ means good and ‘zwijn’ means swine. The euro-sign indicates the promise of economic viability.

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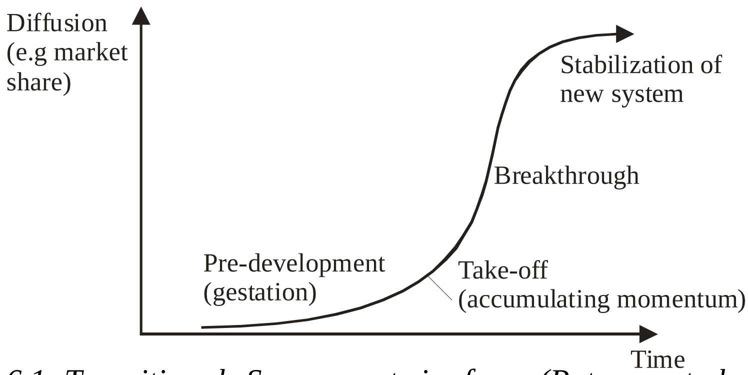
6. Conclusies

Auteurs: alle onderzoekers

Aan de hand van het onderscheid tussen 'global' en 'local' modellen uit de inleiding, trekken we eerst twee typen conclusies:
6.1. Conclusies over algemene transitie-patronen ('outside-in')
6.2. Conclusies over de enactment van transities ('inside-out')
Daarna formuleren we in 6.3 enkele bredere bevindingen en suggesties voor TransForum.

6.1. Conclusies over algemene transitie-patronen ('outside-in')

1. Reconfiguratie als specifiek type transitie-proces
In paragraaf 1.3 onderscheidden we vier typen analytische transitiepaden: 1) transformatie, 2) reconfiguratie, 3) substitutie, en 4) de-alignment en re-alignment. In de literatuur over radicale innovaties, discontinuiteiten en transities wordt meestal (impliciet) verondersteld dat substitutie het enige pad is, waarbij een radicale innovatie ontstaat in niches en vervolgens het bestaande regime omver werpt. In dergelijke transities gaan Dergelijke transities worden dan verondersteld een duidelijke S-curve te volgen (zie Figuur 6.1), waarbij innovatieve 'new entrants' uiteindelijk de bestaande bedrijven vervangen (zie bv. Schumpeter's 'waves of creative destruction' of Christensen's (1997) disruptive technologies).



Figuur 6.1: Transities als S-curve met vier fasen (Rotmans et al., 2001)

Hoewel dit type transities (substitutie) zeker bestaat, suggereren onze case studies dat er in de landbouw veeleer sprake is van een andere transitie-pad, namelijk *reconfiguratie*. In hoofdstuk 2 noemen Berkers en Geels (2008) drie verschillen met het substitutie-pad:

> "Reconfiguration processes deviate from breakthrough transitions in three aspects:
> 1) the process is not driven by *one* major, radical innovation, but by *multiple* (component) innovations,
> 2) these innovations do not compete with the existing system, but are incorporated as add-ons or component replacements; transitions then do not consist of fights between 'old' and 'new' technologies, but are more gradual processes in which new combinations of 'old' and 'new' gradually change the system's architecture in a stepwise fashion,
> 3) incumbent actors are not swept away by new entrants (as in 'waves of creative destruction'), but survive the process; incumbent actors enact the reconfiguration of the system architecture; the *development* of the innovations, however, often is done by other

> (outside) actors. Hence, the transfer of knowledge and innovations to incumbent actors is an important aspect of reconfiguration transitions."

In reconfiguratie-processen wordt niet de ene populatie/industrie vervangen door de andere, maar gaat het erom hoe een bestaande populatie van boeren geleidelijk verandert door de adoptie en integratie van component-innovaties, nieuwe netwerken (bv. met suppliers en afnemers) en andere praktijken ontwikkelen.
* Bij hedendaagse varkenstallen en dieren-welzijn (hoofdstuk 5) gaat het dan om nieuwe voedingssystemen die groepshuisvesting voor fokzeugen mogelijk maken of om varkenstallen waar bepaalde functiescheiding plaatsvindt (Comfort Class varkens).
* Bij hedendaagse glastuinbouw en 'energie uit de kas' (hoofdstuk 4) gaat het dan om nieuwe warmtewisselaars, pijpen naar aquifers etc.
* Bij de historische transitie naar bio-industrie in de varkenshouderij (hoofdstuk 3) ging het om nieuwe voedingssystemen, verwarmingselementen, mestafvoer-componenten, stalsystemen etc.
* Bij de historische mechanisering van de glastuinbouw (hoofdstuk 2) ging het om kolen, olie en gaskachels, boilers en verwarmingscomponenten, kunstmatig licht, besproeiings- en afwateringselementen, etc.

De integratie van deze componenten in bestaande praktijken en systemen gaat vaak gepaard met leerprocessen en articulatie van nieuwe routines en praktijken. Dat kan dan weer leiden tot behoeftes aan verdere component-innvaties (voor andere deelaspecten van het systeem), waardoor op den duur de hele systeem-architectuur kan veranderen, wat dan (vaak ex-post) als transitie wordt geduid.

2) Complicaties in het onderscheid tussen radicale en incrementele innovatie

Omdat transities in specifieke landbouw-sectoren het karakter van reconfiguratieprocessen hebben, is het onderscheid tussen radicale en incrementele innovatie minder geschikt. Dit onderscheid is namelijk impliciet gebaseerd op transities als substitutie-proces, waarbij actoren in bestaande regimes alleen incrementeel innoveren en niche-actoren (outsiders, new entrants) de radicale discontinuiteiten ontwikkelen. In dat transitiepad worden radicaal en incrementeel dus als duidelijke tegenstellingen gebruikt.

Bij een reconfiguratie transitiepad is dit onderscheid echter minder nuttig. Wij trekken hierover de volgende sub-conclusies:

a) In reconfiguraties is minder duidelijk sprake van een *shift* van het ene afgebakende systeem naar het andere. Het is veel moeilijker om duidelijk een 'turning point', discontinuiteit of doorbraak aan te wijzen. De twee historische cases laten zien dat zo'n kantelpunt punt niet echt bestaat. Reconfiguratie-transities zijn meer geleidelijk en continue veranderingsprocessen waarin verschillende onderdelen van systemen stapsgewijs veranderen. Uiteraard zijn sommige stappen groter of kleiner dan andere, maar van echte doorbraak-momenten is minder sprake. In plaats daarvan zien we cumulaties van grotere en kleinere veranderingen. Maar in termen van *uitkomst*, kan deze cumulatie over lange perioden wel tot grote veranderingen leiden. Als je voor beide historische cases de situatie in 1930 vergelijke met 1970 of 1980, dan zijn de regimes zeer verschillend in termen van technieken, actoren en regels/praktijken.
b) Dit kenmerk creëert additionele complicaties wat betreft de *afbakening* van transities. De term 'transitie' refereert namelijk naar een verandering tussen twee

duidelijk afgebakende semi-stabiele toestanden. In Webster's dictionary wordt de term 'transition' bijvoorbeeld omschreven als:

> **1 a :** passage from one state, stage, subject, or place to another **:** CHANGE **b :** a movement, development, or evolution from one form, stage, or style to another
> **2 a :** a musical modulation **b :** a musical passage leading from one section of a piece to another
> **3 :** an abrupt change in energy state or level (as of an atomic nucleus or a molecule) usually accompanied by loss or gain of a single quantum of energy

De term 'regime' was bedoeld om een dergelijke semi-stabiele toestand aan te duiden, en daarom ook nuttig om te spreken over 'regime shifts' en transities. Maar bij reconfiguratieprocessen is het moeilijker om een transitie te definieren als een shift tussen twee coherente regimes. De twee historische cases beginnen beide in 1930 en eindigen in 1970 en 1980. Maar in nadere reflectie is deze periodisering deels willekeurig en ingegeven door externe landschapsinvloeden (de economische crisis van de jaren '30) en de toenemende kritiek op technocratische bestuursstijl (in de jaren 70, o.a. ook opkomst van nieuwe belangengroepen rond milieu en dierenwelzijn). Ook in de jaren 1910, 1920 en 1930 vonden component-innovaties in glastuinbouw en varkensregimes plaats, zodat er geen sprake was van volledige stabiliteit. En in de jaren 1970 en 1980 vonden ook nog allerlei component-innovaties plaats (bv. in genetische tomatenkweektechnieken), zodat ook hier geen sprake was van volledig stabiele regimes in de jaren 70 (waarna alleen nog maar incrementele verandering zou plaatsvinden). Kortom, voor reconfiguratie-transities is de afbakening in de tijd (startpunt en eindpunt van transities in case studies) dus moeilijk, en vaak open voor debat. Voor lopende en toekomstige transities is de implicatie hiervan dat het dus ook moeilijk is om in de tijd aan te geven waar we in 'de' transitie zitten; wanneer we in het ene regime zitten en wanneer in het andere. De vier voorgestelde fasen uit Figuur A (voorontwikkeling, take-off, doorbraak, en stabilisatie) zijn dus minder nuttig.

3) Het belang van concrete experimenten en projecten

In reconfiguratie-transities zijn experimenten en niche-innovatie projecten zeer belangrijk, als mechanisms om de routines en werkwijzen van een populatie (boeren in dit geval) te veranderen. Bij reconfiguratie-transities gaat het namelijk niet om het vervangen van 'oude' door 'nieuwe' actoren, maar om *bestaande* actoren die hun routines en werkwijzen veranderen (mede door de adoptie van niche-innovaties en veranderende netwerken).

De niche-experimenten en projecten worden dus niet gedragen door geheel nieuwe actoren ('new entrants), zoals de literatuur over transities en SNM soms suggereert (zie paragraaf 1.3). Bij reconfiguratie-transities gaat het om regime-actoren die bij niche-experimenten betrokken worden. Dit zijn meestal niet mainstream regime actoren, maar actoren aan de rand van het regime ('fringe actors'), die op bepaalde aspecten toch al wat afwijken van de dominante regime regels en praktijken.[33] In hoofdstuk 5 bijvoorbeeld lieten Elzen *et al.* zien dat bepaalde boeren

[33] Regime-actoren zijn dus niet volledig homogeen. Zeker in grote populaties zoals in de landbouw het geval is, zijn niet alle actoren in een regime gelijk. Er kunnen verschillen zijn in termen van grootte, financiele positie, houding ten opzichte van innovatie, bepaalde morele of religieuze overtuigingen etc.

eind jaren ’80 al vroeg experimenteerden met groepshuisvesting voor fokzeugen. In hoofdstuk 4 wordt hiervoor een nieuw concept geïntroduceerd, t.w. ‘hybride actoren’ die zowel kenmerken van ‘insiders’ als van ‘outsiders’ hebben. Juist die hybride actoren spelen een belangrijke rol in niche ontwikkeling en tevens in het leggen van verbindingen tussen niche en regime waarvoor het concept ‘verankeríng’ wordt geïntroduceerd en uitgewerkt.

Innovatieve niche-projecten worden, zeker in het begin, dus vaak gedragen door boeren die bereid zijn (iets) af te wijken van het bestaande regime. Als deze projecten later succesvol blijken, worden deze afwijkers ex-post vaak 'voorlopers' genoemd. In ‘real time’, echter, worden ze soms met de nek aangekeken of als ‘vreemd’ beschouwd.

Het feit dat alle hoofdstukken laten zien dat innovatieve niche-projecten belangrijk waren of zijn, heeft ook te maken met drie andere, algemene kenmerken van het landbouw-systeem.

a) De kas of de stal is een 'configurational technology' waar meerdere componenten moeten samenwerken. Terwijl de verbetering van afzonderlijke componenten wel goed in laboratoria kan plaatsvinden, geldt dat niet voor het totale systeem (de stal of de kas). Bij de adoptie van nieuwe component-innovaties in dat systeem moet dus in de praktijk blijken of en hoe de nieuwe componenten samenwerken of worden ingepast. De stal of de kas heeft dus kenmerken van een ‘laboratorium in de praktijk’. Pas door daadwerkelijke implementatie kan over het systeem als geheel worden geleerd, iets dat ook wel ‘learning by trying’ wordt genoemd (Fleck, 1994). Dit verklaart mede waarom experimenten en concrete projecten zo belangrijk zijn in de landbouw.

b) Verder speelt de natuur een belangrijke rol in de landbouw. Planten, groenten en dieren zijn complexe systemen waarvan de dynamiek vaak niet helemaal wordt begrepen (wat ook blijkt uit het regelmatig opduiken van onverwachte effecten). Dus de implementatie van nieuwe hardware componenten (of nieuwe bio-technische innovaties) kunnen tot onverwachte neveneffecten in natuurlijke systemen leiden. Ook daarom heeft implementatie van innovaties in de landbouw altijd een experimenteel karakter. Een voorbeeld is het gebruik van antibiotica in de varkenssector wat in de na-oorlogse periode een onverwacht stimulerend effect op de groei van vee bleek te hebben (hoofdstuk 3). Het veelvuldig gebruik van antibiotica als groei-stimulans bleek later (sinds de jaren ’90) echter ook te leiden tot het ontstaan van zeer resistente ziektekiemen, die mogelijk ook voor de mens gevaarlijk zijn. Een ander voorbeeld was dat de introduktie van kunstmatige verwarming en besproeiing in de glastuinbouw, ook leidde tot nieuwe ziektes in de tomatenteelt (vanwege warmer en vochtiger binnenklimaat), wat weer aanleiding was voor onderzoek naar nieuwe tomatenrassen en chemische bestrijdingsmiddelen (hoofdstuk 2).

c) Boeren hebben veelal een sceptische houding ten aanzien van theoretische, academische argumenten. Hoewel ze waardering hebben voor innovaties die van Universiteiten (of andere suppliers) komen, willen ze eerst in de praktijk zien dat deze ook echt werken ('talk is cheap; seeing is believing').

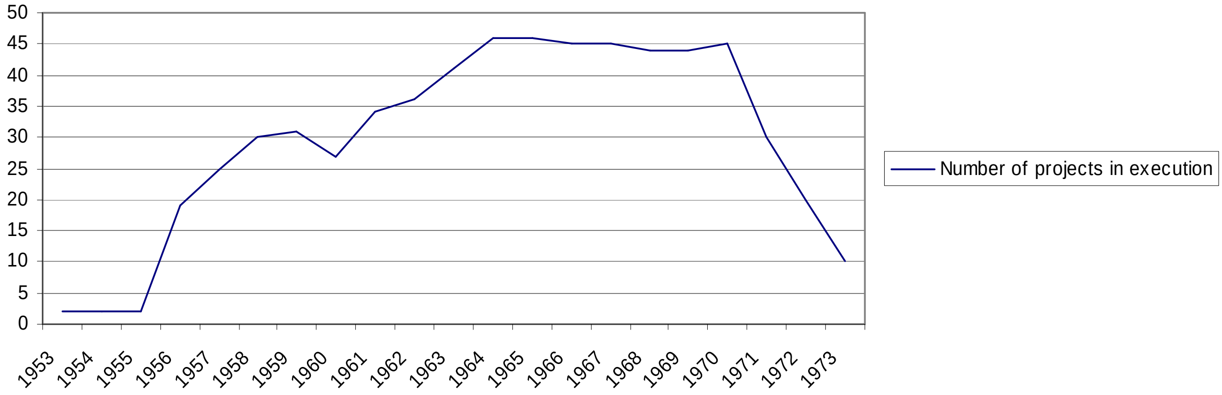
Vanwege deze kenmerken spelen concrete (demonstratie)projecten in landbouw-transities een zodanig belangrijke rol, dat Berkers en Geels (hoofdstuk 2) dit een bij uitstek typerend kenmerk voor de sector noemen.

4) Sequenties van projecten en leertrajecten

De historische studies laten ook zien dat enkelvoudige projecten, of zelfs tientallen projecten, niet voldoende zijn om transities te bewerkstelligen. Hoofdstuk 3 liet zien dat de transitie naar mechanisering, rationalisering, schaalvergroting (1950-1970) werd begeleid en mogelijk gemaakt door vele honderden, zo niet duizenden, projecten, die boeren in staat stelden nieuwe praktijken en werkwijzen te ontwikkelen en aan te leren. Hoofdstuk 3 benadrukt het belang van dit 'bottom-up' leren in concrete boerenpraktijken, en stelt dit 'paradigma' naast twee andere, meer traditionele paradigma's, die ofwel economische processen benadrukten ofwel politiek en planmatige processen.[34]. Om dit leren te faciliteren, werden in de periode 1950-1970 allerlei experimenten en demonstratie-projecten georganiseerd, via het OVO-netwerk, investerings- en subsidiefondsen en regionale streekverbeteringsprojecten.

Voor dat laatste type projecten laat Figuur 6.2 goed zien dat er sprake was van geleidelijke opschaling: eerst twee pilotprojecten (in Kerkhove en Rottevalle 1953-1956), en daarna steeds meer projecten (Karel, 2005; zie ook hoofdstuk 3). Dit projectmatige beleid voor streekverbetering werd lang volgehouden (zo'n 20 jaar), en leidde daardoor tot cumulatieve leertrajecten. Deze streekverbeteringsprojecten richtten zich niet op individuele boerderijen, maar op hele gebieden en regios. Hele gemeenschappen werden bij de projecten betrokken, waardoor niet alleen sociale controle and stimulans plaatsvonden (via nieuwe netwerken), maar ook onderlinge kennisuitwisseling plaatsvond. Deze projecten gaven subsidie voor de aanschaf van nieuwe (technische) component-innovaties, maar alleen op voorwaarde dat de regio zelf een projectplan opstelde en ook de voortgang monitoorde (wat dus visie-ontwikkeling, leerprocessen en netwerkbouw stimuleerde). De voorlichtingsdienst organiseerde ook bezoekjes aan deze regionale projecten om andere boeren te overtuigen van het nut van de adoptie en ontwikkeling van nieuwe praktijken en werkwijzen. Karel schat dat door alle maatregelen zo'n 71.000 boeren op een of andere manier in contact is geweest met de in totaal 132 streekverbeteringsprojecten.

[34] Traditionele analyses van de landbouwmoderniserings hebben twee vormen (hoofdstuk 3):
1) Een economisch verhaal over veranderende factor costs, investeringen en prijs/performance verbeteringen. Vooral hogere lonen leidden in die verklaring tot een shift van arbeid naar kanpitaal en hogere arbeidsproduktiviteit. Dalende prijzen voor varkensvlees leidden verder tot druk op boereninkomens wat een drijfveer was voor kostprijsverlaging en schaalvergroting.
2) Een institutioneel-politiek verhaal waarin de overheid (Mansholt) een nieuwe visie ontwikkeld, vervolgens de centrale boerenorganisaties overtuigde, en aarna die visie implementeerde via maatregelen die boeren overtuigen en prikkelden: a) een expansie van het OVO-netwerk: meer research en meer voorlichters die boeren ging bezoeken, meer scholen waarin boerenzonen nieuwe inzichten werd geleerd; b) maatregelen om investeringen te stimuleren: bank-garanties voor leningen, goede uitkoopregelingen voor boeren die wilden stoppen (Ontwikkelings en Sanerings Fonds, 1963), c) structural adjustment programs, waar de overheid veel geld stopte. In 1970, wordt geschat dat de overhead bijna 5% van het BNP besteedde aan verschillende structural adjustment maatregelen (Van den Brink, 1990: 11). Tussen 1947 and 1985, werd naar schatting cumulatief zo'n 13.8 miljard gulden uitgegeven (Van den Bergh, 2004: 171). Hierbij ging het ook om dure land verbeteringsprojecten met investeringen in infrastructuur (bv. het vlak maken van land oppervlakten, verbeteren van kanalen en sloten voor afwatering, aanleg of verbetering van regionale wegen, waterleiding en elektriciteitsinfrastructuuur.



Figuur 6.2: Aantal regionale streekverbeterings projecten (gebaseerd op gegevens uit Karel, 2005: 124)

Voor transities is dus ten eerste van belang dat sequenties van meerdere projecten in een bepaalde richting op elkaar voortbouwen en kunnen optellen wat leidt tot innovatieve leertrajecten. Ten tweede, moeten de ervaringen van projecten ook breder worden vertaald of verankerd raken in het bredere regime. Zo niet, dan zal ook een sequentie van projecten weinig breder transitie-effect hebben.

<u>5) Rol van crises en het belang van *timing* en *context*</u>

De case studies laten zien dat crises en shocks vaak een belangrijke rol spelen in transities[35]:

* De economische crisis van de jaren ’30 (1929-1936)[36] leidde bijvoorbeeld tot een veel grotere betrokkenheid van de overheid bij de landbouw (hoofdstuk 2 en 3).[37] De crisis leidde dus tot grote veranderingen in het sociale netwerk, en vormde het begin van corporatische netwerk (het ‘groene front’) dat tussen 1930 and 1980 de landbouw domineerde (met zeer sterke banden tussen boerenbonden, het ministerie en landbouwwoordvoerders van politieke partijen). De crisis leidde tot vele tijdelijke maatregelen om de nood te lenigen en de sector te beschermen (hoofdstuk 2 en 3).[38]

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[35] Bij Rijkswaterstaat, wiens investeringsbudget en verantwoordelijkheid voor grote technische waterbouwkundige projecten na de watersnoodramp van 1953 sterk toenam, doet nog steeds de volgende zegdwijze de ronde: “Geef ons heden ons dagelijks brood, en af en toe een watersnood” (Lintsen *et al*., 2004).

[36] Bijvoorbeeld het export volume van groenten daalde tussen 1929 en 1935 met meer dan 50% (Bieleman, 1992). De prijs voor tomaten daalde van zo’n 25 gulden in 1930 tot 9.54 gulden in 1935 (hoofdstuk 2). De (nationale en internationale) economische crisis reduceerde ook de export en nationale consumptie van vlees, en bedreigde in meer algemene zin het voortbestaan van vele boeren.

[37] Voor de jaren ’30 was het overheidsbeleid liberaler en meer geleid door marktbeginselen. De overheid was toen voornamelijk bij de landbouw betrokken via het OVO-netwerk (dat sinds de jaren 1890 geleidelijk was uitgebouwd).

[38] De overheid hielp boeren bijvoorbeeld met rentevrije leningen en directe inkomenssteun. Als veilingprijzen beneden een bepaald nivo daalden, compenseerde de overheid het verschil met dat nivo. Om verdere prijsdaling tegen te gaan werden produktiebeperkende maatregelen ingevoerd en import-tarieven verhoogd. De schaal van overheidssteun van zeer groot. Tussen 1933 en 1936 waren de totale uitgaven van het nieuw gecreerde Landbouw Crisis Fonds zo’n 200 miljoen gulden per jaar, hetgeen ongeveer 40% van het nationale landbouwinkomen vormden (Bieleman, 1992: 238-239).

Maar de nieuw gevormde netwerken en de betrokkenheid van de overheid bleef ook daarna bestaan. op de veel sterkere rol van overheid (bescherming) (betrokkenheid, begin van OVO).
* De Tweede Wereldoorlog had ook een aantal effecten die de naoorlogse modernisering positief beïnvloedden. Ten eerste, creëerde de hongersnood maatschappelijke en politieke legitimatie voor grote politieke naoorlogse betrokkenheid bij de landbouw, onder het motto 'nooit meer honger'. Financiële steun en sturend beleid, die bij het op gang brengen van de landbouwtransitie een grote rol speelden, werden als legitiem gezien. Ten tweede, was de betrokkenheid van de overheid bij het maatschappelijke leven tijdens de oorlog sowieso sterk toegenomen (voedseldistributie, opvang, verzorging, bescherming). De oorlog leidde dus zowel tot nieuwe beleidsmatige 'capabilities' bij de overheid als nieuwe percepties bij de bevolking over een grotere maatschappelijke overheidsrol. Ten derde, leidde de oorlog tot enorme schade in de landbouw.[39] Het herstel van deze schade creerde ruimte voor de aanschaf van nieuwe componenten, die soms al in de jaren '30 ontwikkeld waren, maar door de moeilijke economische omstandigheden niet gekocht konden worden. De directe na-oorlogse jaren waren ook economische moeilijk. Maar de Marshall-hulp (1948-1952) en de economische groei van de jaren '50 en '60 gaven hiervoor meer ruimte.
* De varkenspest in 1997 (en de televisiebeelden van grote aantallen dode varkens die machinaal werden opgehaald en verwijderd) leidde tot grote maatschappelijke verontwaardiging en de perceptie dat de praktijken in de bio-industrie ethisch en maatschappelijk niet acceptabel waren. Deze maatschappelijke verontwaardiging creerde grote druk op politiek om 'iets' te doen en de varkenssector scherper aan te pakken. Bij fokzeugen werd toen groepshuisvesting via regelgeving min of meer afgedwongen, ook al had dat weinig directe koppeling met de varkenspest (hoofdstuk 5). Bij de vleesvarkens had de crisis minder grote effecten en leidde (slechts) tot het vergroten van de verplichte ruimte per varken van 0,7 naar 0,8 m^2.

Het effect van shocks en crisis hangt echter ook af van *timing* en *culturele* context. De verschillende invloed van de varkenspest (1997) op de deel-sectoren van vleesvarkens en fokzeugen wordt in hoofdstuk 5 verklaard aan de hand van *timing* ten aanzien van lopende innovatie-trajecten. Bij de fokzeugen was al sinds eind jaren '80 consternatie ontstaan over de 'kettingzeug' en de wenselijkheid van groepshuisvesting. Dat laatste vereiste echter innovaties in voedingssystemen (om te voorkomen dat sterke zeugen de zwakkeren bij het voeden zouden verdringen moest een systeem worden ontworpen waarin varkens gescheiden en sequentieel gevoed werden). De eerste generatie voedingssystemen werden direct in de praktijk toegepast, waarbij het percentage boeren met groepshuisvesting groeide tot ongeveer 5% van de populatie. Praktijkproblemen en tegenvallende resultaten met de eerste generatie systemen leidde echter tot onvrede, slechte berichten in de vakpers, en een sectorbrede negatieve perceptie. Het percentage boeren daalde dan ook van 5 tot 2 % midden jaren '90. Ondertussen hadden onderzoekers de techniek verbeterd, wat leidde tot een tweede generatie voedingssystemen. De negatieve perceptie was echter zo verhard dat

[39] In de glastuinbouw was bijvoorbeeld 1.786.300 m^2 glas van kassen beschadigd of gebroken. Herstel van de oorlogsschade vereiste bijvoorbeeld 900.000 m^2 grote glas platen, 568.000 m^2 kleine glas platen, 1.670.000 raamframes, 175.000 meter verwarmingspijpen, 30.000 meter rails in kassen, 400 centrale verwarmingsboilers, en and 500 motor pompen (hoofdstuk 2).

de sector er niet aan wilde. De varkenspest creerde echter een ‘window of opportunity’ voor deze niche-innovatie. Beleidsmakers konden deze innovatie (en de praktijk van groepshuisvesting) doordrukken omdat de techniek voldoende verbeterd en gestabiliseerd was, en omdat voorstanders konden wijzen naar de 2% boeren die aantoonden dat groepshuisvesting ook economisch rendabel kon zijn. De *timing* van de crisis viel dus gelukkig, waardoor techniek, beleid, economie en cultuur op een positieve manier gekoppeld konden worden.

Voor vleesvarkens werden de jaren ’80 vooral gedomineerd door mestproblemen. Er waren dus veel minder innovatietrajecten gericht op dierenwelzijn en nieuwe stalconcepten. Voor zover dierenwelzijn wel speelde, was er sprake van een veelheid aan thema’s (onverdoofd castreren, gebrek ene ruimte, niet kunnen wroeten en spelen, niet naar buiten kunnen, knippen van staarten en tanden; leven op harde, koude en glibberige betonnen vloeren). De innovatie-aandacht rond dierenwelzijn was dus ook veel minder gefocust dan bij fokzeugen, en dus meer verspreid, waardoor ook geen stabilisering plaatsvond. Ten tijde van de varkenpest waren er dus geen ontwikkelde en gestabiliseerde niche-innovaties die van de ‘window of opportunity’ gebruik konden maken (of door beleidsmakers doorgedrukt konden worden). De *timing* van de crisis viel bij de vleesvarkens minder gelukkig, waardoor ook de effecten minder groot waren.

De implicatie van deze comparatieve case study (hoofdstuk 5) is dat het voor systeem-innovaties onvoldoende is om gewoon te wachten tot er een crisis of schok plaats vind. Als er geen alternatieve niche-innovaties zijn ontwikkeld (en liefst ook al enigszins in de praktijk toegepast waardoor concrete ervaring is ontstaan), kan de ‘window of opportunity’ niet gebruikt worden. Deze conclusie versterkt dus het belang van conclusie 3 en 4, over het belang van ontwikkelen van alternatieven, en experimenteren in de praktijk. Ook als deze alternatieven niet direct breder kunnen doorbreken is het belangrijk om nieuwe capabilities en technieken te ontwikkelen, zodat een eventuele kans later beter benut kan worden.

Het belang van de *culturele context* is goed zichtbaar bij de economische crisis van de jaren ’30. In dat tijdvak was de landbouw nog een groot, zichtbaar en belangrijk onderdeel van de maatschappij, waar ook een groot deel van de beroepsbevolking werkzaam was. In hoofdstuk 3 geeft Geels de volgende omschrijving van de culturele plek van landbouw:

> “Before the war, farmers were perceived as moral backbone of society, invaluable to a healthy society. They were presumed to have specific rural virtues such as attachment to the land, solidarity, indifference to the whims of urban culture, common sense, hard work, and thrift (De Haan, 1993). This ideology explains why small farms were supported when they faced difficulties.”

Deze positieve culturele betekenis van de landbouw verklaart mede waarom de overheid bereid was tot zeer aanzienlijke beschermingsmaatregelen tijdens de economische crisis van de jaren ’30.

6.2. Conclusies over enactment van transities ('inside-out')

In onze historische casussen hadden boeren een duidelijk belang bij de transities, simpel gezegd een hoger inkomen. De investeringen in nieuwe technologie en praktijken hadden een bedrijfs-economische logica gericht op *performance* *improvements* (lagere kosten per eenheid door schaalvergroting, en hogere *performance* door beter voer, nieuwe kassen etc.).

In onze contemporaine case-studies ligt dat duidelijk anders en komt de druk voor verandering van buiten de sector. Het zijn vooral externe partijen die aandacht vragen voor dierenwelzijn (in de varkenscasus) en reductie van CO_2 emissies (in de glastuinbouw casus). Daarmee ontstaat er een spanning tussen de regimedynamiek en de externe druk, hetgeen ontwikkelingen in beweging kan zetten die (op termijn) tot transities kunnen leiden. De analyses van beide case-studies focussen op verschillende onderdelen van dat proces, t.w.:

- Varkenscasus: Hoe draagt de koppeling van normatieve druk met andere processen bij aan het uitlokken van verschillende transitiepaden?
- Glastuinbouwcasus: Hoe dragen koppelingen tussen niche- en regimeontwikkeling bij aan het in gang zetten van transitie processen?

Dit definieert twee invalshoeken op een zelfde algemene vraagstelling waardoor, zoals hieronder zal blijken, de conclusies elkaar versterken.

1. Normatieve druk en koppeling met andere processen

In een stabiele situatie kan de ontwikkeling van regimes worden gekenschetst als een ‘reproductie’ pad: regime actoren reproduceren bestaande praktijken en opereren binnen relatieve stabiele *rule-sets*. Dat wil echter niet zeggen dat er geen spanningen binnen bestaande regimes zijn (Greenwood en Hinings, 1996). Coherentie en spanning bestaan tegelijkertijd en regimes blijven stabiel zo lang de bindende krachten sterker zijn dan de spanningen, d.w.z. zo lang er voldoende congruentie bestaat tussen de regime actoren (Grin en Van de Graaf, 1996).

Dat geldt ook voor externe druk. Ook die zal niet tot regimeverandering leiden zo lang de bindende krachten te sterk zijn. Dat betekent dat een destabilisatie van regimes afhangt van twee ontwikkelingen: 1) toenemende externe druk en 2) afnemende coherentie binnen het regime (bijv. op het punt van regelgeving, markt, cultuur, technologie).

De normatieve druk komt in eerste instantie vaak van sociale bewegingen. Om bij te kunnen dragen aan het verlaten van het reproductie pad moet deze druk 1) toenemen en 2) koppelen aan economische, technologische en beleidsontwikkelingen. Wat betreft de toenemende druk onderscheidt de *Socal Movement Theory* (SMT) een drietal processen, t.w. 1) *framing processes*, 2) *resource mobilisation* en 3) *political opportunity structures* (McAdam et al., 1996; Davis et al., 2005).

SMT is ontleend aan de beleidswetenschappen en sociologie en besteedt daarom nauwelijks aandacht aan technologie. In onze analyse is deze invalshoek daarom gekoppeld aan een typologie van Van de Poel (2000) die naast maatschappelijke bewegingen nog een tweetal andere *outsiders* onderscheid: 1) wetenschappers en ingenieurs en 2) *outsider* bedrijven.

Binnen de varkenscasus zijn twee deelsectoren onderscheiden, t.w. de huisvesting van drachtige zeugen en de huisvesting van vleesvarkens. In het eerste geval hebben maatschappelijke protesten sinds het begin van de jaren ’80 (vooral van de Dierenbescherming) na drie decennia het gewenste resultaat gehad, t.w. dat zeugen vanaf 2013 in groepen moeten worden gehuisvest. In het tweede geval zijn de successen veel beperkter, t.w. iets meer ruimte per varken (van 0,7 m^2 naar 0,8 m^2 voor nieuwe stallen na 1998 en naar 1 m^2 voor alle stallen in 2013), een kleine toename van dicht vloeroppervlak en afleidingsmateriaal in de stal.

Een vergelijking van beide casussen leert dat wat betreft de drie dimensies van normatieve druk de *resource mobilisation* en de *political opportunity structures* voor beide casussen vergelijkbaar waren. Er was echter wel een duidelijk verschil in *framing*. In de fokzeugen casus richtte het protest zich vooral op het houden van zeugen aan een ketting, door de Dierenbescherming aangeduid als de *kettingzeug*. Voor vleesvarkens was er een minder sterke focus in probleemdefinitie. Protesten richtten zich onder andere op de ammoniak- en geuremissies, mestafzet, beschikbare vloerruimte, het knippen van staarten en tanden, onverdoofd castreren, aandeel dichte vloer, etc. Deze variëteit in probleemdefinities leidde tot het ontwikkelen van een breed scala aan alternatieven: de Hercules stal, Varkens in Comfort Class, Canadese strooiselstal, biologische houderij. Verder wist de varkenshouderij een sterke *counter-framing* voor het voetlicht te brengen, t.w. dat additionele eisen aan de conventionele houderij een bedreiging vormden voor de economische rentabiliteit (die toch al zeer onder druk stond) en de Nederlandse exportpositie. Door de meer gefocusseerde *framing* was de *normatieve druk* in de zeugen casus hoger dan in de vleesvarkenscasus wat het verschil in uitkomsten deels kan verklaren.

Het tweede deel van de verklaring is gelegen in de koppeling van deze druk met andere deelprocessen, t.w. ontwikkelingen op het terrein van technologie, markt en beleid. In de fokzeugen casus ondersteunden die ontwikkelingen de normatieve druk terwijl dat in de vleesvarkenscasus veel minder het geval was. Wat betreft de technologie bijvoorbeeld was er voor de houderij van fokzeugen een eenduidig alternatief, t.w. groepshuisvesting. Voor vleesvarkens echter werd er een scala aan alternatieven ontwikkeld.

Een belangrijke additionele bevinding is dat de *timing* van het koppelen van de druk met deze additionele ontwikkelingen van cruciaal belang is zoals ook al werd geconcludeerd op basis van de historische studies (conclusie 5 in voorgaande sectie). Na de uitbraak van de varkenspest (1997) nam door de maatschappelijke druk ook de beleidsdruk om 'iets te doen' in korte tijd enorm toe. Op dat moment lag er voor de fokzeugen een (technisch) alternatief 'klaar' dat korte tijd daarna verplicht werd gesteld. Voor vleesvarkens werd pas in 2005 een eerste alternatief houderijsysteem ontwikkeld (Hercules) maar op dat moment was de beleidsdruk vrijwel verdwenen en het Hercules ontwerp kwam in een bureaulade terecht. Na de opkomst van de Partij voor de Dieren nam de maatschappelijke en politieke belangstelling voor dierenwelzijn weer snel toe en vervolgens richtte alle beleidsmatige interesse zich op het alternatief dat toen volop in ontwikkeling was, Varkens in Comfort Class. Hoewel de ontwerpen voor de Hercules stal nog steeds 'klaar' in de bureaulades liggen is daar weinig belangstelling voor.

2. Onzekerheid over toekomstige ontwikkelingspaden

Geels en Schot onderscheiden in een recent artikel (2007) een 4 tal transitiepaden, t.w. 1) *transformation*, bestaande uit vooral een interne ontwikkeling binnen een regime in antwoord op interne of externe druk; 2) *reconfiguration*, waarbij regime actoren bepaalde niche-innovaties adopteren in antwoord op externe of interne druk; combinaties van oude en nieuwe elementen leiden tot een langzame reconfiguratie van de basiskenmerken van het systeem; 3) *substitution*, waarbij alternatieve praktijken of radicale niche-innovaties het bestaande systeem overnemen; 4) *de-alignment and re-alignment*, waarbij het regime door grote landschapsdruk snel desintegreert, gevolgd door een periode waarin de ontwikkeling van diverse alternatieven in niches tot een periode van onzekerheid en experimentatie leidt waarvan er uiteindelijk één dominant wordt.

De contemporaine varkens case-studie analyseert hoe een verschillende mate van koppeling tussen externe normatieve druk en een drietal andere ontwikkelingen (beleid, markt, technologie) tot verschillende soorten transformatiepaden kan leiden. Dit is samengevat in Tabel 6.1.

	Normative	Regulatory	Market	Technology	**Transition pathway**
Dry sows regime (before 1990)	+	+	0	+	Transformation (reconfiguration in niche)
Dry sows regime (1990-1997)	+	0	0	+	Transformation (reconfiguration in niche)
Dry sows regime (after 1997): Group housing	++	++	+	+	Reconfiguration
Fattening pigs regime (before 1997)	+	0	0	0	Reproduction
Fattening pigs regime (after 1997): toys and somewhat larger stables	+	0/+	0	0	Reproduction; some groups target transformation
Fattening pigs niches (2000s): Hercules stable, Pigs in Comfort Class, Canadian bedding	++	0	0	+	Reconfiguration (no wider diffusion as yet)
Intermediary market segment niche (Jumbo)	+	0	0/+	+	Reconfiguration (no wider diffusion as yet)
Organic farming market niche	+	0	0/+	+	Substitution (no wider diffusion as yet)

Tabel 6.1 Mate van druk richting dierenwelzijn op verschillende dimensies en het daaruit resulterende type transitiepad (0 = afwezig; 0/+ = klein; + = matig; ++ = sterk)

Uit de studie blijkt dat tijdens transities 'in the making' verschillende soorten ontwikkelingspaden naast elkaar bestaan. Hoewel sommige daarvan dominant zijn, is de toekomst in essentie open, d.w.z. dat actoren hun percepties, doelen en strategieën kunnen wijzigen afhankelijk van interacties en de koppeling met verdere culturele, economische, politieke en technologisch ontwikkelingen.

Deze fundamentele onzekerheid blijkt ook duidelijk in de glastuinbouwcasus. Bepaalde ontwikkelingen die begonnen vanuit een systeeminnovatieve ambitie (een reconfiguratie pad) bleken ook binnen het bestaande systeem van nut te zijn en werden daar ingepast waardoor ze bijdroegen aan een transformatie pad. Ook van het omgekeerde geval zijn voorbeelden: WKK, bijvoorbeeld, was oorspronkelijk onderdeel van een transformatiepad, vooral bedoeld om de elektriciteitskosten van tuinders laag te houden. Door de koppeling met beleidsstimulering heeft dat zich echter ontwikkeld tot een situatie waarin het voor tuinders een tweede bron van inkomsten is geworden, waaraan ze soms meer verdienen dan met de verkoop van gewassen. Hierdoor zijn tuinders tevens energieproducenten en -handelaren geworden, een duidelijk voorbeeld van een reconfiguratie pad.

Dit is een belangrijke bevinding voor diverse partijen die programma's opzetten om systeeminnovaties uit te lokken. Bij transities 'in the making' is het onderscheid met incrementele innovatie vaak onduidelijk en kunnen er ook haasje-over effecten plaatsvinden. Het is belangrijk om daar enerzijds alert op te zijn en anderzijds, om duurzame ontwikkeling te bevorderen, niet exclusief in te zetten op ontwikkelingen met een systeeminnovatieve ambitie.

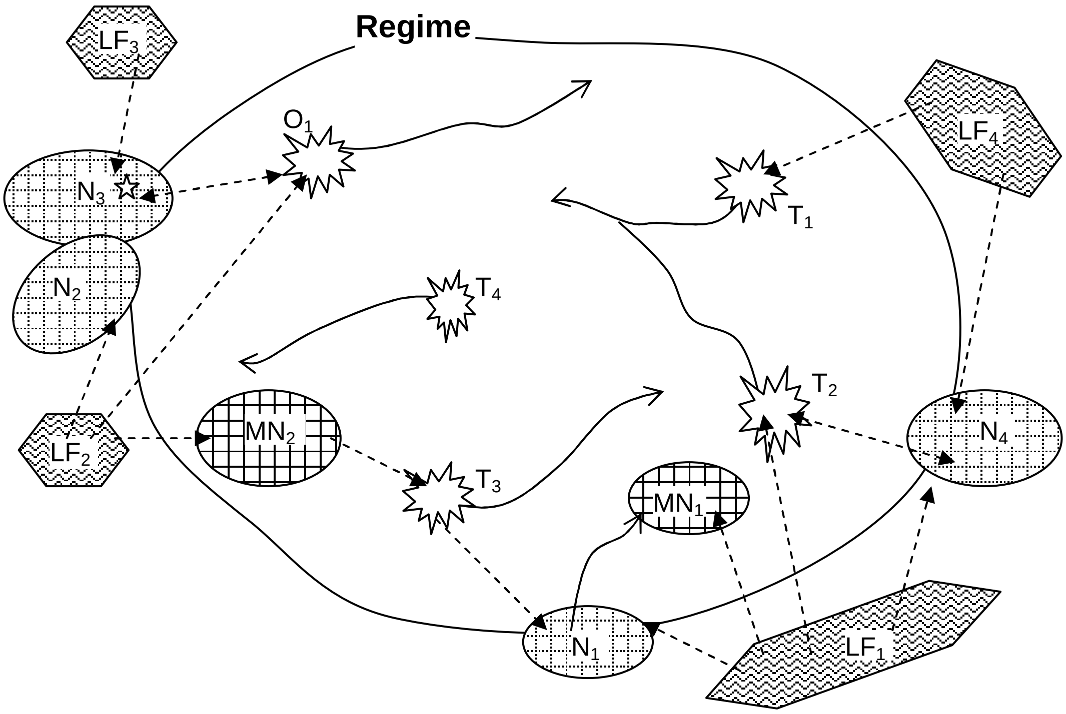
3. Processen van verankering

Historische studies van transities hebben een lange termijn perspectief en een 'outside in' benadering. Verschillende auteurs hebben betoogd dat daarin buiten beeld blijft hoe de interacties tussen niches en regimes precies verlopen en hoe koppelingen daartussen tot stand komen en benadrukken daarmee impliciet het belang van een 'inside out' benadering (Smith, 2007). In de contemporaine studies hebben we ingezoomd op dergelijke koppelingsprocessen. Voortbouwend op werk van Loeber (2003) en Grin & Van Staveren (2007) gebruiken we daarbij het concept *verankering*. Verankering drukt uit dat er nieuwe verbindingen ontstaan die echter ook weer verbroken kunnen worden. We hebben het concept verder verfijnd door onderscheid te maken tussen drie vormen van verankering, t.w. technologische, netwerk en institutionele verankering.

Om daarmee koppelingsprocessen te kunnen analyseren was het nodig een meer verfijnde representatie te maken van het multi-level perspectief met de volgende eisen:

- niches en regime overlappen elkaar in zekere mate;
- landschapsdruk beïnvloed zowel niche als regime;
- niche, regime en landschap staan niet in een hiërarchische relatie;
- het generieke heuristische idee van het MLP intact laten.

Het resultaat is weergegeven in figuur 6.2 waarin is aangegeven hoe de drie 'niveaus' (niche, regime en landschap) elkaar kunnen beïnvloeden.



Figuur 6.2: Multi-level processen in systeeminnovatie (LF = landschapsfactor; N = niche; voor een verdere uitleg zie de tekst onder figuur 3 in Hoofdstuk 4)

Met dit model transformeert de vraag naar verankering naar de analyse van wat er gebeurd in en rond de overlappingsgebieden tussen niche en regime. Op basis van de glastuinbouw casus blijkt dan dat er een nauwe wisselwerking bestaat tussen de verschillende vormen van verankering en dat ze in de tijd op willekeurige wijze op elkaar kunnen volgen (Figuur 4 in Hoofdstuk 4 geeft daarvan een impressie). Er zijn daarin een aantal verschillende patronen geïdentificeerd.

- Translation: Een concept (technologische verankering) wordt niet zomaar overgenomen door een grotere groep (netwerk verankering) maar wordt daarbij vaak in meerdere of mindere mate gewijzigd;
- Opportunity: Veel studies vanuit MLP benadrukken de rol van *problemen* als drijvende kracht voor verandering. Maar minstens even belangrijk zijn nieuwe *kansen* die door eerdere ontwikkelingen zijn ontstaan;
- Internalisation: De noodzaak tot terugdringen van CO_2-emissies was eerst een externe landschapsdruk maar is inmiddels een sterke interne drijvende kracht binnen de glastuinbouwsector geworden.
- Alignment: Koppeling en onderlinge versterking van verschillende vormen van verankering leidt tot meer robuuste nieuwe configuraties. Deze conclusie sluit nauw aan bij de hiervoor beschreven conclusie op basis van de varkenscasus.

Deze analyse laat zien dat verankering een nuttig concept is om te analyseren hoe koppelingen tussen niche- en regimeontwikkelingen kunnen ontstaan (en weer kunnen worden verbroken). De volgende stap is om op basis van een grotere variëteit aan case-studies te pogen om daar specifieke patronen in te identificeren.

4. Rol van outsiders en hybride actoren

Hierboven is aangegeven dat *outsiders* een belangrijke rol kunnen spelen in innovatieprocessen, ofwel doordat zij maatschappelijke druk voor verandering leveren ofwel door het ontwikkelen en aanbieden van alternatieven voor een bestaand systeem. Op basis van de glastuinbouwcasus is geconstateerd dat het onderscheid tussen *insiders* en *outsiders* verfijning behoeft. Van de Poel (2000, p.384) geeft twee karakteriseren van *outsiders*:

1. Ze staan buiten of zijn op z'n minst marginaal t.o.v. het regime;
2. Sommige van de belangrijkste regels m.b.t. technologische ontwikkeling worden door hen niet gedeeld.

In hoofdstuk 4 worden diverse actoren genoemd die in de innovatieprocessen een belangrijke rol hebben gespeeld, waaronder de installateurs van kassen, voorlopers onder de telers, het Productschap Tuinbouw, het InnovatieNetwerk. Deze actoren voeldoen niet aan Van de Poel's criteria omdat ze ofwel niet marginaal zijn t.o.v. van het regime ofwel de belangrijkste regels wel delen. Tegelijkertijd zijn ze sterk gecommitteerd aan het realiseren van (radicale) verandering om aan de maatschappelijke eisen te voldoen. Deze groep actoren noemen we *hybride actoren* die een categorie vormen tussen *insiders* en *outsiders* en belangrijke karakteristieken van beide vertonen.

Koppelen we dit aan *verankering* dan blijken deze *hybride actoren* een cruciale stimulerende rol te spelen. Zij opereren op het overlappingsgbied tussen regime en niche in figuur 6.2 (Figuur 4 in Hoofdstuk 4 zoomt daar verder op in) en doen dat in diverse netwerken rond bijv. demonstratieprojecten, het programma 'Kas als Energiebron', het 'Actieplan voor een Klimaatneutrale glastuinbouw' en het Synergie businessplatform. Dergelijke netwerken worden aangeduid als *hybride fora* die een specifieke locatie vormen waar verankering plaatsvindt. De studie geeft aanwijzingen (die op basis van een groter scala aan casussen zou moeten worden onderzocht) dat *verankering in een hybride forum* een belangrijke tussenstap vormt in de ontwikkeling van niche naar regime. Een belangrijke conclusie van deze studie is dat hybride actoren die opereren in hybride fora een cruciale rol spelen in het stimuleren van verankering als opstap naar radicale innovatie.

6.3. Aanbevelingen voor de uitlokking van (systeem-)innovaties

In deze sectie doen we op basis van onze vier studies een aantal aanbevelingen voor het uitlokken van (systeem-)innovaties richting duurzaamheid. Hoewel de empirische basis voor deze aanbevelingen beperkt is tot vier case studies, springen er een aantal zaken uit.[40]

<u>1) Bescheidenheid versus doortastendheid</u>
Het aantal praktijk-projecten in TAG is relatief beperkt, zeker als we het vergelijken met de duizenden projecten in de landbouwtransitie in de jaren '50 en '60. TAG kan nuttige aanzetten geven, maar de impact zal enigszins beperkt blijven. Meer fundamenteel is echter dat uitkomsten onzeker zijn en dat ingezette ontwikkelingen door latere ontwikkelingen compeet *overruled* kunnen worden. Hier past dus een

[40] Deze bevindingen worden ondersteund door ervaringen van de onderzoekers in diverse andere onderzoeksprojecten en door conclusies uit andere literaturen.

zekere bescheidenheid wat betreft de impact die men met dergelijke projecten wil realiseren.

Toch is het nuttig om innovatieprojecten op te zetten en interventies te plegen in een bestaand systeem. Daardoor worden nieuwe ontwikkelingen in gang gezet en gaan nieuwe netwerken ontstaan (waaronder hybride fora) zoals de contemporaine glastuinbouw casus laat zien. Ook als die op een gegeven zouden lijken te falen betekent dit nog niet dat de inspanningen voor niets zijn geweest omdat bepaalde concepten op een later moment toch weer actueel kunnen worden. Een voorbeeld is het ‘gesloten kas’ concept dat na een aantal jaren onderzoek in het begin van de jaren ’90 in het vergeetboek terecht kwam maar tegenwoordig weer in het centrum van de belangstelling staat.

<u>2) Radicaal of incrementeel</u>

Het idee van transitie door reconfiguratie (zoals in de landbouw veelal het geval is, zie paragraaf 6.1) heeft ook implicaties voor de projecten in Transforum. Er worden soms vraagtekens gezet bij het systeem-innovatieve gehalte van de projecten (de mate van radicaliteit). Daar is op basis van de historische cases (en theoretische ideeen) wel wat op af te dingen. Mensen die dergelijke kritiek uiten, denken vaak vanuit een ander type transitie-pad: technological discontinuity and substitution (ook Schumpeter en anderen in de innovatie literatuur). Daar is dan sprake van radicale innovaties (nieuwe techniek en kennisbasis; bv. auto's versus paard-en-wagen), die in niches ontwikkeld moeten worden en gedragen zijn door radicale projecten.

Maar bij reconfiguratie-paden is de transitie een meer stapsgewijs proces, waarbij een bestaande populatie van actoren hun regels/praktijken, technieken en netwerken geleidelijk veranderen. Men moet dus bestaande actoren overtuigen in plaats van een nieuwe groep actoren ('new entrants') laten groeien. En dat gaat beter stapsgewijs dan radicaal. Als teveel wordt afgeweken van een bestaand systeem, zal het moeilijk zijn om bestaande actoren mee te krijgen. Beter is het om verschillende kleine stapjes te nemen, en steeds nadruk te leggen op 'terugvertalen' of 'verankeren' van ervaringen uit leerprojecten in de bestaande groep.

Daarbij hangt de mate van radicaliteit af van uit wiens perspectief dat wordt beoordeeld. Voor consumenten lijkt het verbieden van zeug aan ketting een grote shift en wat meer stalruimte voor vleesvarkens niet. Voor de boer is het echter precies andersom. Verder laat de glastuinbouwcasus zien dat verandering die als ‘incrementeel’ zijn begonnen na verloop van tijd tot zeer ‘radicale’ veranderingen kunnen leiden (WKK) en vice versa (adiabatische koeling). Daardoor kunnen er ook haasje-over effecten tussen radicale en incrementele paden plaatsvinden.

De belangijke les hieruit is dat men zich niet blind moet staren op 'radicaliteit' in transities, zeker als het om reconfiguratieprocessen gaat.

<u>3) Verankering in hybride fora</u>

De studie geeft aanwijzingen dat *verankering in een hybride forum* een belangrijke tussenstap vormt in de ontwikkeling van niche naar regime. Een belangrijke conclusie van deze studie is dat hybride actoren die opereren in hybride fora een cruciale rol spelen in het stimuleren van verankering als opstap naar radicale innovatie. Het onderscheid tussen drie verschillende vormen van verankering (technologisch, netwerk en institutioneel) kan worden gebruikt als een diagnose instument om te analyseren of rond een bepaald project wel in voldoende mate aan de verschillende vormen van verankering aandacht wordt besteed. De concepten *hybride actoren* en *hybride fora* kunnen daarbij een instrument vormen om precieser na te gaan of men binnen een project wel de juiste actoren heeft betrokken en of de vormgeving van een project wel adequaat is toegesneden op het beoogde doel.

4) Timing
Een aantal van onze casussen laten duidelijk het belang van *timing* zien, vooral wat betreft het breder kunnen doorbreken van niche-innovaties naar het regime. Het heeft weinig zin om via regulering verandering af te dwingen op het moment dat er onvoldoende verankering rond mogelijke alternatieven heeft plaatsgevonden. Verder onderzoek zal moeten uitwijzen waar daarbij precies op zou moeten worden gelet maar de ervaring laat zien dat men zich daar lang niet altijd van bewust is.

6.4. Epiloog

Door de vier case studies van twee deelsectoren (glastuinbouw en varkens) hebben we een aantal belangrijke bijdrages geleverd aan wetenschappelijke inzichten in het verloop van innovatieprocessen. Sommige daarvan leiden tot een aantal nieuwe denkrichtingen die in verder onderzoek uitgewerkt moeten worden. Tevens hebben we op basis daarvan een aantal aanbevelingen kunnen ontwikkelen voor het uitlokken van (systeem-)innovaties. Daarmee hebben we in deze studie een fundament gelegd voor interessant vervolgonderzoek dat zowel wetenschappelijk interessant als maatschappelijk relevant is.

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