Ansätze einer akteursbasierten Innovationserklärung

Konzeptionelle Überlegungen, empirische Untersuchung und agentenbasierte Modellierung

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1. Einleitung

Innovationen sind nicht nur die Grundlage eines entwickelten Lebensstandards, sie sind angesichts des zunehmenden Verbrauchs und der Schädigung von natürlichen Ressourcen durch die globale Produktion und Konsumption auch die Grundlage für die Ausrichtung des globalen Wirtschaftens hin zu einer ökologisch vertretbaren Wirtschaftsweise. Die Frage der Genese, Umsetzung und Verbreitung von Innovationen als Herzstück der wirtschaftlichen und damit auch der gesellschaftlichen Entwicklung ist insofern als Gegenstandsbereich der Ökonomik von besonderer Relevanz. Damit rückt die Akteursebene[1] in den Fokus, denn es sind Akteure, die Entscheidungen zu Innovationen treffen, die Innovationen durchführen und die die Verbreitung von Innovationen realisieren.

Dabei ist die Auseinandersetzung mit den akteursbasierten Grundlagen von Innovationen und deren Wechselwirkung mit dem ökonomischen Geschehen nicht neu, im Kern beschäftigen sich Ökonomen seit der industriellen Revolution hiermit. So sind beispielsweise Inventionen, konkret die Verbesserung von bestehenden und die Erfindung neuer Maschinen, bereits für Adam Smith neben den gestiegenen Fertigkeiten der Arbeiter und der Arbeitsteilung eine der drei Grundlagen des Produktivitätswachstums (s. Smith 2007/1776[2], 10f., 72). Smith geht dabei davon aus, dass die durch die Arbeitsteilung induzierte Spezialisierung Inventionspotentiale erschließt, und unterscheidet drei Arten von Inventorpersönlichkeiten: *Erstens* Arbeiter, die Verbesserungen an den Maschinen einführen, an welchen sie tätig sind, *zweitens* spezialisierte Maschinenbauer und *drittens* „philosophers or men of speculation, whose trade it is not to do anything, but to observe everything; and who, upon that account, are often capable of combining together the powers of the most distant and dissimilar objects“ (ebd., 12). Smiths Akteure sind insofern mit unterschiedlichen Befähigungen ausgestattet, deren Art nach Smith überwiegend von Erziehung und gesellschaftlichen Einflüssen abhängt

[1] Unter dem Begriff ‚Akteur‘ werden im Folgenden, soweit nicht anders spezifiziert, sowohl Einzelindividuen als auch Unternehmen als Entitäten subsumiert.

[2] Soweit hier und im Folgenden in dieser Arbeit zu relevanten Werken zwei Publikationsjahre angegeben werden, bezieht sich das erste auf das Erscheinungsjahr der jeweils zitierten Auflage und das zweite nachrichtlich auf das Erscheinungsjahr der ersten Veröffentlichung. Letzteres wird nur beim ersten Zitieren der Fundstelle angegeben und findet sich nicht im Literaturverzeichnis.

(s. Smith 2007, 17) und deren Ausprägung durch die Erfahrung bestimmt ist. Smith nimmt damit eine akteurszentrierte Perspektive ein, welche über hundert Jahre später von Thorstein Veblen sowie insbesondere von Joseph Schumpeter prominent vertreten wurde und welche sich in modernen Ansätzen zur Erklärung des wirtschaftlichen Wandels wiederfindet.

Eine derart gefasste Auseinandersetzung mit den Grundlagen des wirtschaftlichen Geschehens und dem Akteur ist jedoch weit entfernt von der Perspektive der Standardökonomik und deren abstrakten Annahmen über das Akteursverhalten (u.a. vollständige Information, unbeschränkte Rechenkapazitäten, Nutzenmaximierung als einziges Ziel des Homo oeconomicus; Gewinnmaximierung unter der Prämisse der als bekannt vorausgesetzten Produktionsfunktion bei den Unternehmen) und über den Wirtschaftsprozess (der stetig in Gleichgewichtszuständen resultiert). Innovation als Handlungsmodus von Akteuren, seien es Individualakteure oder Unternehmen, thematisiert die Standardökonomik allenfalls am Rande (entsprechend sind dann selbst die modern geprägten Wachstumsmodelle, welche den technologischen Fortschritt beinhalten, im Kern nicht mikrofundiert).

Vor diesem Hintergrund findet sich bereits bei Veblen und auch bei Joseph Schumpeter eine grundlegende Kritik am Akteurs- und Wirtschaftskonzept der Standardökonomik, welche, in unterschiedlicher Ausprägung, in alternativen Modellen des wirtschaftlichen Wandels und der Rolle des Innovationsgeschehens resultiert. Eine systematische und explizierte Konzeption eines entsprechenden, das Innovationsgeschehen fokussierenden ökonomischen Akteurskonzeptes findet sich jedoch erst ab der Mitte des letzten Jahrhunderts im Werk von Herbert Simon bzw. der Carnegie-School (im Folgenden nach Dosi (2004, 213) mit ‚SCP' für „Simon/Carnegie Perspektive abgekürzt). Allerdings ist zu konstatieren, dass eine Auseinandersetzung hiermit und im Grunde auch mit dem Werk von Schumpeter und Veblen zumindest bis in die 80er Jahre des letzten Jahrhunderts relativ wenig Resonanz im Rahmen der ökonomischen Theorieentwicklung fand, obwohl zumindest seit den 50er Jahren mit der Innovationsökonomik eine verstärkte, insbesondere auch empirisch fundierte Beschäftigung mit dem Gegenstandsbereich der Innovation erfolgte. Mit dem Erfolg des Werkes von Nelson und Winter (1982), welches die Evolutionsökonomik als einen alternativen Ansatz zur Standardökonomik begründete, wurde dann jedoch ein Rahmen für die Etablierung eines am Innovationsgeschehen orientierten, auf die Akteursebene fokussierenden und sich auf die SCP beziehenden Forschungsprogrammes geschaffen. Gleichwohl lässt sich heute immer

noch feststellen, dass die Evolutionsökonomik die akteursbasierte Perspektive auf das Innovationshandeln zwar thematisiert, jedoch die Etablierung eines alternativen Akteurskonzeptes noch aussteht.

Die vorliegende Arbeit, welche als kumulative Dissertation fünf Artikel beinhaltet, nimmt dies als Ausgangspunkt und will einen Beitrag zur Ausgestaltung der akteursbasierten Fundierung der Evolutionsökonomik leisten, in dessen Mittelpunkt das Innovationsgeschehen steht. Die Arbeit kombiniert dabei theoretische Konzeptionen mit methodischen Umsetzungen. Als spezifischer Ansatz der vorliegenden Arbeit kann mit Blick auf die theoretische Konzeption verstanden werden, dass die fünf Aufsätze in unterschiedlichem Umfang jeweils Teilbereiche des Werkes der SCP aufnehmen. Hierbei wird insbesondere auf diejenigen Aspekte eingegangen, die sich mit dem Innovationsentscheiden bzw. -handeln von Einzelakteuren sowie von Unternehmen befassen. Diese werden dabei an spezifische Fragestellungen adaptiert und in diesem Zusammenhang, soweit es notwendig erscheint, zuspitzt und ergänzt. Hierzu nimmt die vorliegende Arbeit auch Befunde der benachbarten Sozialwissenschaften auf, insbesondere der Psychologie und der Kognitionswissenschaft sowie der Vertrauensforschung als interdisziplinäres Forschungsfeld. Hinsichtlich der methodischen Umsetzung wird *erstens* mit einer empirischen Erhebung zum Gegenstandsbereich Umweltinnovationen ein Teilaspekt des Innovationskonzeptes der SCP, die Entscheidung zur Innovation, untersucht. Damit wird zum einen ein Beitrag dazu geleistet, einer von Silva und Teixeira (2009, 615ff.) identifizierten methodischen Schwachstelle der Evolutionsökonomik zu begegnen, nämlich der mangelnden empirischen Mikrofundierung mittels Akteursbefragungen, und zum anderen wird dazu beigetragen, ein aktuelles, im Sinne der obigen Bemerkung gesellschaftlich und ökonomisch relevantes Themenfeld in die evolutionsökonomische Diskussion einzubringen. *Zweitens* wird, aufbauend auf Nelson und Winter (1982), die Methode der agentenbasierten Computermodellierung angewendet, zum einen, um die Mikroebene der Dynamik von Wissensaustausch und Vertrauen in Forschungs- und Entwicklungskooperationen tiefergehend zu analysieren und zum anderen, um im Sinne von Veblen und insbesondere von Schumpeter die aus den Innovationsentscheidungen und -handlungen von Akteuren resultierenden (emergenten) Effekte auf der Meso- und der Makroebene des wirtschaftlichen Handelns und deren Rückwirkung auf die Mikroebene zu erfassen.

Im Folgenden wird in Abschnitt 2 zunächst auf den theoretischen Hintergrund eingegangen, der den fünf Artikeln zu Grunde liegt, soweit dieser der Ökonomik zuzurechnen ist (in den fünf Artikeln finden sich dann die jeweiligen Bezugnahmen auf die benachbarten Sozialwissenschaften bzw. die Kognitionswissenschaft). Hierzu wird in Abschnitt 2.1 auf den konzeptionellen Hintergrund eingegangen, indem zunächst die relevanten Ansätze bei Veblen und Schumpeter als Ahnherren einer akteursbasierten Betrachtung des wirtschaftlichen Wandels skizziert werden (Abschnitt 2.1.1). Abschnitt 2.1.2 erfasst als einen ersten Schwerpunkt der Darstellung des theoretischen Hintergrundes der vorliegenden Arbeit das Konzept des Innovationshandelns der SCP. Hierzu wird zunächst das in der SCP enthaltene Akteurskonzept im Allgemeinen dargestellt (Abschnitt 2.1.2.1) und hierauf aufbauend das Konzept des Innovationshandelns von Unternehmen (Abschnitt 2.1.2.2). Abschnitt 2.2 widmet sich den zwei bereits angesprochenen aktuellen Diskussionsfeldern. Hierzu wird in Abschnitt 2.2.1 ein, in Bezug auf die Akteursfundierung kritischer, Überblick über Entwicklung und Fragestellung der modernen Innovationsökonomik als generischer, mit dem Forschungsgegenstand Innovation befasster wissenschaftlicher Disziplin gegeben. Anschließend wird in Abschnitt 2.2.2 in einem zweiten Schwerpunkt der Darstellung des theoretischen Hintergrundes umfassender auf die Evolutionsökonomik eingegangen. Deren unterschiedliche Ansatzpunkte werden aufgezeigt und es wird die Frage gestellt, inwieweit die Evolutionsökonomik mit einer akteursbasierten Fundierung im Sinne der Bezugnahme auf die SCP befasst ist. Dieser Abschnitt schließt mit einer entsprechenden, kurzen bibliometrischen Analyse und einer Diskussion möglicher Hintergründe der hieraus resultierenden Befunde. Abschnitt 2.3 bietet eine kritische Würdigung der vorgestellten Ansätze und Befunde. Hierauf aufbauend werden dann in Abschnitt 3 die Gegenstandsbereiche der fünf Artikel vorgestellt und diese in Bezug zu den Ausführungen in Abschnitt 2 gesetzt, d.h. insbesondere in Bezug zu der kritischen Würdigung in Abschnitt 2.3. Abschnitt 4 erfasst die fünf Artikel, dies sind im Einzelnen die Artikel

1. ‚Invention and Innovation as creative problem solving activities' (Beckenbach/Daskalakis 2012) (Artikel 1, Abschnitt 4.1),
2. ‚Behavioural foundations of innovation surveys' (Beckenbach/Daskalakis 2008) (Artikel 2, Abschnitt 4.2),
3. ‚Behavioural determinants of eco-innovation. A conceptual and empirical study' (Daskalakis 2013a) (Artikel 3, Abschnitt 4.3)

4. ‚A procedural model of trust dynamics and knowledge exchange in collaborative R&D' (Daskalakis 2013b) (Artikel 4, Abschnitt 4.4) sowie
5. ‚Agent based modelling of novelty creating behavior and sectoral growth effects – Linking the creative and the destructive side of Innovation' (Beckenbach et al. 2012) (Artikel 5, Abschnitt 4.5).

Die Arbeit schließt mit einer Zusammenfassung und einem Ausblick auf weitere Forschungsfragen (Abschnitt 5).

Anzumerken ist noch, dass in der vorliegenden Arbeit im Sinne des Oslo-Manuals (OECD/Eurostat 2005, 46ff.) zunächst ein weiter Innovationsbegriff zu Grunde gelegt wird. Soweit nicht anders spezifiziert, umfasst der Term ‚Innovation' insofern unterschiedliche Innovationsarten (d.h. Produkt-, Prozess-, Marketing- und Organisationsinnovationen) und unterschiedliche Neuerungsgrade (d.h. radikale Innovationen, inkrementelle Innovationen und Imitationen), wobei die Analyseebene die Firma im Sinne des Oslo-Manuals bzw. der Individualakteur ist. Eine Innovation auf Unternehmensebene kann also zum Beispiel sowohl eine radikale Marktneuheit als auch eine Imitation sein. Im Rahmen der vorliegenden Arbeit interessieren u.a., wie oben angesprochen, zudem die Prozesse, die dazu führen, dass sich Akteure dafür entscheiden, Innovationen durchzuführen, sowie die Prozesse der Diffusion und deren Resultate. Dies alles unter den Begriff der Innovation zu fassen, kann zu einer Reduktion der Eindeutigkeit von Untersuchungsgegenständen und damit zu mangelnder Präzision von Argumenten und Analysen führen. Soweit spezifische Erkenntnisgegenstände diskutiert werden, wird in der vorliegenden Arbeit deswegen jeweils dargestellt, in welchem Sinne der Begriff Anwendung findet, bzw. werden die dem jeweiligen Gegenstandsbereich zuzuordnenden konkreten Begriffe verwendet.

2. Theoretischer Hintergrund

2.1. Konzeptioneller Hintergrund der akteursbasierten Innovationserklärung

2.1.1. Veblen und Schumpeter

Veblen kann sicherlich als einer der ersten Ökonomen, vielleicht sogar als der erste Ökonom gelten, der die Grundlagen des wirtschaftlichen Wandels betrachtet und dies mit einer massiven Kritik an der Engführung der marginalistischen Perspektive verknüpft. So liefert Veblen in seinem grundlegenden Artikel ‚Why is Economics not an Evolutionary Science' (Veblen 1898) ausgehend von einer Kritik am damaligen Stand des standardökonomischen Ansatzes (s. hierzu auch ausführlicher Veblen 1909) nicht nur ein Plädoyer und ein Konzept für eine evolutorische Perspektive auf das Wirtschaften, in deren Rahmen Innovationen eine zentrale Rolle einnehmen, sondern auch ein Plädoyer und einen Vorschlag für ein realistisches Akteurskonzept (s. auch Buenstorf 2012).

Veblen geht dabei davon aus, dass technologische Veränderungen (im Sinne von Inventionen) zu unumkehrbaren Veränderungen von wirtschaftlichen Prozessen führen und dass die Entwicklung von derartigen Innovationen pfadabhängig ist sowie auf dem bestehenden Wissensstock aufbaut (s. Veblen 1906, 598; Veblen 1919b, 326ff.). Der Akteur als Treiber der Veränderung ist für ihn ein zentraler Forschungsfokus einer evolutorischen Perspektive:

> „It is in the human material that the continuity of development is to be looked for; and it is here, therefore, that the motor forces of the process of economic development must be studied if they are to be studied in action at all." (Veblen 1898, 388; s. auch ebd., 387)

Dem standardökonomischen, hedonistischen Akteurskonzept schreibt Veblen in diesem Zusammenhang die Tauglichkeit in Bezug auf eine derartige Analyse ab:

> „In all the received formulations of economic theory, whether at the hands of English economists or those of the Continent, the human material with which the inquiry is concerned is conceived in hedonistic terms; that is to say, in terms of a passive and substantially inert and immutably given human nature. The psychological and anthropological preconceptions of the economists have been those which were accepted by the psycho-

logical and social sciences some generations ago." (Veblen 1898, 389; s. auch Veblen 1909, 621ff.)

Veblen geht in seinem alternativen Akteurskonzept davon aus, dass das (zielgerichtete) Verhalten von Akteuren (auch) auf ererbten Eigenschaften beruht und von Traditionen, Umfeldbedingungen und der materiellen Ausstattung geprägt ist (s. Veblen 1898, 390ff.). Habituelles Handeln ist hierbei ein grundlegender Handlungsmodus. Das Innovationshandeln ist demgegenüber die intrinsisch motivierte Suche nach Möglichkeiten, neue Ziele zu erreichen, und induziert Veränderungen (ebd.). Als relevante Akteursmerkmale für Letzteres werden von Veblen Expertenwissen, Erfahrung, Experimentierfreudigkeit, spezifische Fähigkeiten, Durchsetzungsstärke, Eifer und Initiative genannt (s. Veblen 1919a, 50; 1919b, 328). Da Akteure alleine nicht in der Lage sind, das komplexe und vielfältige Wissen technologischer Veränderungen aufzunehmen, ist hierbei kooperatives (Innovations-)Handeln notwendig (s. 1919b, 324ff.). Veblen betont, dass das Markthandeln von Individuen in Interaktion mit dem Umfeld erfolgt. Umfeld (einschließlich Institutionen) und Akteure entwickeln sich hierbei in einem Wechselspiel von Lernprozessen, Innovationen, Adaptionen und Habitualisierung in einem rückgekoppelten Prozess der wirtschaftlichen Evolution (s. Veblen 1898, 390f.; 1909, 598; 1919b, 328ff.; s. auch Buenstorf 2012, 1f.).

Ist bei Veblen die Auseinandersetzung mit dem Themenfeld Innovation jedoch nur ein Bestandteil seines theoretischen Ansatzes, so setzt sich Schumpeter bekanntlich als Erster systematisch aus einer akteursbasierten Perspektive mit dem Phänomen der Innovation auseinander und stellt dieses in den Mittelpunkt seiner Theorie der wirtschaftlichen Entwicklung. Schumpeter betrachtet hierbei explizit nicht die Invention, sondern die Innovation im Sinne der Umsetzung einer Invention.[3] Die wirtschaftliche Entwicklung erfolgt dabei nach Schumpeter pfadabhängig und interaktiv in Zyklen (s. Schumpeter 1993/1926, 334; 2008b/1927, 22; 2010/1939, 105), induziert jeweils durch Innovationen sowie deren Diffusion, und geht einher mit einem „Prozess der schöpferischen Zerstörung" (1950/1942, 134; s. auch Artikel 4) bestehender Marktstrukturen. Die Innovation steht insofern im Mittelpunkt dieses Prozes-

[3] Schumpeter subsumiert unter dem Begriff Innovation Folgendes: Produkt- und Prozessinnovationen, die Erschließung neuer Absatzmärkte, die Erschließung von neuen Rohstoffquellen und/oder von Vorprodukten sowie die Schaffung bzw. das Durchbrechen von Monopolstellungen (Schumpeter 1993, 100f.; s. u.a. auch Schumpeter 2006, 159; 2010, 92).

ses. Treiber ist dabei der Unternehmer[4], der in diesem Sinne nicht nur der zentrale Akteurstyp im Konzept von Schumpeter ist, sondern die zentrale Kraft der wirtschaftlichen Entwicklung.[5]

Schumpeter setzt sich dann bekanntlich damit auseinander, welche spezifischen Merkmale Unternehmer aufweisen (s. auch Daskalakis 2002, 28ff.). Wie auch Veblen thematisiert er hierbei kritisch das Akteurskonzept der traditionellen Ökonomik (s. Schumpeter 1993, 116ff.) und setzt sich zudem, wiederum kritisch, mit deren Annahmen in Bezug auf das wirtschaftliche Gleichgewicht auseinander (Schumpeter 2006, 489).

Schumpeter stattet dabei seinen Unternehmer mit innovationsspezifischen Eigenschaften aus, hierzu gehören Persönlichkeitsmerkmale wie Mut und die Befähigung, Neues aufzugreifen (Inventionen) (s. Schumpeter 1993, 128; 2008d/1928, 384). Möglicher Widerstand gegen

[4] Schumpeter differenziert zwei wirtschaftliche Akteurstypen: die Wirte und die Unternehmer (s. zu Letzteren im Text). Erstere leiten zwar Unternehmen und/oder sind auch Inhaber von Unternehmen, sie unterscheiden sich jedoch vom Akteurstyp Unternehmer darin, dass sie in ihrem Handeln grundlegend neuerungs- und entscheidungsavers sind, mithin auch keine nennenswerten Innovationen durchführen (Schumpeter 2006, 129, 162). Die einzige Innovationsart, die Schumpeter dem Wirt zuschreibt, ist die weniger aufwendige Verbesserungsinnovation (Schumpeter 1993, 119, Fn 19). Da dieser Akteurstyp für den vorliegenden Sachverhalt nicht vorrangig von Bedeutung ist, wird auf diesen nicht weiter eingegangen.

[5] In der Literatur wird häufig davon ausgegangen, dass der ‚späte' Schumpeter mit seinem im Jahr 1942 publizierten Werk ‚Kapitalismus, Sozialismus und Demokratie' (KSD) seine ‚frühe' Perspektive auf die Relevanz des Unternehmers aufgegeben habe und davon ausgehe, dass Inventionen routinemäßig in großen, vertrusteten Unternehmen durchgeführt werden (die diese dann auch in Innovationen umsetzen) (s. z.B. Freeman 1982, 10; Nelson/Winter 1982, 278; Witt 2002, 16f.). Dies würde implizieren, dass die Grundannahmen, die in der Theorie der wirtschaftlichen Entwicklung formuliert werden, keine Gültigkeit mehr aufweisen, da diese auf dem Konzept einer von vielen einzelnen innovierenden Unternehmern und damit auch von vielen einzelnen innovierenden Unternehmen geprägten Marktwirtschaft beruht. Allerdings ist nach Auffassung der Autorin diese Differenzierung zwischen einem ‚frühen' und einem ‚späten' Schumpeter (bzw. zwischen ‚Mark I' und ‚Mark II', s. Freeman 1982, 2) nicht korrekt. So ist u.a. zu berücksichtigen, dass Schumpeter das Modell der vertrusteten Wirtschaft als ein Zukunftsszenario darstellt (s. auch Fagerberg 2003, 133f.). Hierzu führt er etwa in dem Artikel ‚Creative Response in Economic History' (Schumpeter 2008c), welcher in 1947, also nach Erscheinen des Werkes KSD erstmals publiziert wurde, aus, dass einiges auf eine solche Entwicklung hinweisen würde, aber: „It is for the historian to establish or to refute it." (Schumpeter 2008c, 158) Festzustellen ist weiterhin, dass Schumpeter dass Modell der vertrusteten Wirtschaft im Kern nicht weiterentwickelte. Zudem finden sich in Schumpeters späteren Publikationen sowohl Auseinandersetzungen mit der Rolle des Unternehmers als auch eine Weiterentwicklung des Unternehmerbegriffes (s. im Text in diesem Abschnitt). Ebenso wird in dem Werk ‚Konjunkturzyklen', welches 1939 publiziert wurde, die Unternehmerpersönlichkeit behandelt (z.B. Schumpeter 2010, 93) und das Unternehmertum sowohl für kleinere als auch für große Betriebe diskutiert (s. ebd., 110f.). Spiegelbildlich nimmt bereits der ‚frühe' Schumpeter in der ersten und auch der zweiten Auflage der ‚Theorie der wirtschaftlichen Entwicklung' (Schumpeter 2006, 284; 1993, 102) sowie in weiteren Aufsätzen (Schumpeter 2008, 384; 1928, 486) auf die Innovationsaktivitäten großer Konzerne Bezug (s. ähnlich auch Hagedoorn 1996; Langlois 2002, 7f.). Insofern ist Langlois Recht zu geben, welcher Folgendes feststellt: „Schumpeter's ideas were remarkably consistent from at least 1928 (three years before he came to the U. S.) until his death." (Langlois 2002, 2)

Innovationen wird vom Unternehmer nicht als Problem, sondern eher als Anreiz (s. Schumpeter 2006/1912, 132) angesehen und er ist bereit, die Risiken auf sich zu nehmen, die mit der Innovation verbunden sind (s. Schumpeter 2006, 120, 163; 2010 KJZ, 112). Die Innovationshandlung ist insofern überwiegend intrinsisch determiniert, in diesem Sinne ist „[...] das wirtschaftliche Handeln […] Selbstzweck“ (Schumpeter 2006, 141), bei dem Motivation und Ziel kongruent sind (s. Schumpeter 2006, 141ff.). Schumpeter nennt weiterhin zwei Gruppen von entsprechenden handlungsdeterminierenden Motiven. Die erste umfasst Leistungsaspekte wie „Traum und [...] Wille, ein privates Reich zu gründen“ (Schumpeter 1993, 138) bzw. „Freude am Erfolg haben“ (Schumpeter 2006, 141), „Siegerwillen“ (Schumpeter 1993, 138) bzw. „die Freude am Siege über andere“ (Schumpeter 2006, 141). Die zweite und für Schumpeter wichtigere Gruppe umfasst kreative Aspekte wie „die Freude am Neugestalten, am Schaffen neuer Formen“ (Schumpeter 2006, 142; s. auch Schumpeter 1993, 138) sowie den Drang zum Experimentieren (Schumpeter 2006, 143).

Das Unternehmertum ist dabei ein temporärer Handlungsmodus, welcher parallel zu anderen Handlungsmodi ausgeführt werden kann, etwa zu routinisierten Managementaktivitäten (s. Schumpeter 2006, 171ff.; 1993, 114f., 147; 2008a, 259ff.; 2008c, 151f.; 2010, 111). Insbesondere in seinem späteren Werk weitet Schumpeter den Unternehmerbegriff auf Führungskräfte mit entsprechenden Befugnissen und Fähigkeiten oder auf Gruppen von Individuen in Unternehmen aus („coporate personality“; 2008a, 261, 268; s. auch Swedberg 1991, 172; Fagerberg 2003, 133). In diesem Sinne wird dann auch das Innovationshandeln von Unternehmen zum Gegenstandsbereich des schumpeterianischen Modells der wirtschaftlichen Entwicklung. Zudem diskutiert Schumpeter in seinem späteren Werk als eine weitere Determinante des Innovationshandelns die Reaktion auf Änderungen von exogenen Daten. Dies wird insbesondere in Schumpeter (2008c) expliziert: Unternehmerisches Handeln von Einzelindividuen oder von Unternehmen ist dann auch dadurch charakterisiert, dass auf gegebene exogene Veränderungen von Umfeldzuständen nicht mittels rein adaptiver Prozesse reagiert wird, sondern dass die Veränderungen im Sinne einer „creative response“ (ebd.) Innovationen induzieren.

2.1.2. Die Simon/Carnegie Perspektive (SCP)

2.1.2.1. Das Akteurskonzept im Allgemeinen

Herbert Simon, Nobelpreisträger der Wirtschaftswissenschaften, beschäftigte sich Zeit seines Forscherlebens mit der Frage des Entscheidens und Handelns von Akteuren und dabei auch des Innovationsentscheidens und -handelns. Dabei legte er eine interdisziplinäre Perspektive zu Grunde, die sowohl in der Ökonomik als auch in der Psychologie, der Kognitionswissenschaft und der Forschung über die künstliche Intelligenz verankert war (s. hierzu ausführlicher Dasgupta 2003). Die angesprochene interdisziplinäre Perspektive findet sich bereits in Simons Frühwerk ‚Adminstrative Behavior' (1997c/1947) wieder sowie in seinen gemeinsamen Forschungen mit James March und Richard Cyert ‚Carnegie Institute of Technology' (s. March 1994, 533) und den hieraus resultierenden Publikationen, insbesondere den Werken ‚Organisation und Individuum' (March/Simon 1993/1958) sowie ‚The behavioral theory of the firm' (Cyert/March 2001/1963). Diese drei Hauptwerke umreißen dabei den Kern dessen, was heute als ‚Carnegie-School' bezeichnet wird. Die interdisziplinäre Perspektive zeigt sich auch in einer Vielzahl von Co-Autorenschaften und Forschungskooperationen. Neben den bereits genannten ist hier insbesondere die Zusammenarbeit mit Allen Newell im Bereich der Problemlösungsforschung zu nennen, welche der Kognitionswissenschaft zuzurechnen ist (s. z.B. Newell/Simon 1972).

Die Ausführungen über das Akteurskonzept der SCP in diesem Abschnitt sind als eine akzentuierte Zusammenfassung der Forschungen der drei Autoren zu verstehen und umfassen auch die auf Einzelindividuen bezogenen und/oder eher kognitionswissenschaftlichen bzw. dem Bereich der künstlichen Intelligenz zuzuordnenden Forschungen Simons. Der zentrale Forschungsfokus der SCP ist dabei die Analyse des zielgerichteten Handelns und Entscheidens von Akteuren. Betrachtet werden hierbei sowohl Individualakteure als auch Unternehmen im Sinne von Entitäten sowie Akteure in Unternehmen.[6]

Das Akteurskonzept der SCP ist explizit als Gegenmodell zum standardökonomischen Ansatz konzipiert worden, welchen es umfassend kritisiert. Demnach basiert das mikroökonomische Theoriegebäude der Neoklassik auf abstrakten, realitätsfernen Annahmen und kann dieses

[6] Die aus dem (ökonomischen) Akteurshandeln resultierenden marktbezogenen Folgen werden, im Unterschied zu den Ansätzen von Veblen und insbesondere von Schumpeter, nur am Rande betrachtet.

somit nicht erfassen, wie ökonomische Akteure in dynamischen und unsicheren und insoweit auch komplexen Situationen realiter handeln und entscheiden (s. hierzu und zu Folgendem u.a. Cyert/March 2001, 4ff.; Simon 1955, 99; 1959, 262; 1979, 496f.; 1978a, 347; 1997b, 395). Diese Kritik fasst Simon in seiner Nobelpreisrede wie folgt zusammen:

> „There can no longer be any doubt that the micro assumptions of the theory – the assumptions of perfect rationality – are contrary to fact. It is not a question of approximation; they do not even remotely describe the processes that human beings use for making decisions in complex situations." (Simon 1978a, 366)

Die SCP setzt nun dem Konzept des umfassend informierten sowie nutzenmaximierenden Einzelakteurs, der mit voller Antizipation der Handlungsergebnisse, unendlichen Rechenkapazitäten, einem eindeutigen, vollständigen, konsistenten und autonomen Präferenzsystem ausgestattet ist, bzw. dem Konzept der gewinnmaximierenden Unternehmung, die (noch einfacher gefasst als Einzelakteur) über eine Produktionsfunktion abgebildet wird, bei welcher die Funktionselemente und deren Verknüpfung als bekannt vorausgesetzt werden, ein Akteurskonzept entgegen, welches den Anspruch auf eine gehaltvollere Abbildung des Handelns und Entscheidens hat.

Das wohl bekannteste und in der Literatur am häufigsten thematisierte Kernelement des Akteurskonzeptes der SCP ist das ursprünglich von Simon (s. bereits Simon 1946) formulierte Konzept der beschränkten Rationalität. Nach diesem ist das Handeln und Entscheiden ökonomischer Akteure grundlegend durch zwei Faktoren beschränkt: „(a) limits on his ability to perform and (b) limits on his ability to make correct decisions" (Simon 1946, 64; s. ebenso Simon 1997c, 46). Zu (a) gehört die (auch genetisch determinierte) Ausprägung von Fertigkeiten und Fähigkeiten, etwa die physische Kraft und die Reaktionszeit; zu (b) sind die kognitiven Beschränkungen zu zählen, u.a. die Begrenzung des Kurzzeitgedächtnisses, die Kapazität des Langzeitgedächtnisses sowie die beschränkte Aufmerksamkeitsspanne und die Geschwindigkeit und Art von Denkprozessen (ebd.). Die Ausprägung dieser Merkmale determiniert die individuelle Informationsaufnahme und Wissensverarbeitung grundlegend (s. u.a. Simon

1955, 101; 1959, 272; 1963, 710; 1997c, 46). Bei komplexen Umfeldzuständen[7] sind Akteure dann nicht in der Lage, alle relevanten Informationen zu überschauen, mit der Folge, dass die interne kognitive Abbildung, d.h. die mentale Repräsentation des Handlungsumfeldes, und das tatsächliche Handlungsumfeld nicht übereinstimmen (s. auch Newell/Simon 1972, 82).

Damit rückt die Frage in den Vordergrund, wie und auf welcher Basis Akteure angesichts kognitiver Beschränkungen, komplexer Handlungsumfelder und daraus resultierender unvollständiger Umgebungswahrnehmung Ziele bilden, Entscheidungen fällen, Handlungen durchführen oder Handlungsergebnisse bewerten, sowie auch die Frage, wie neue Handlungen (im Sinne von Innovationen) generiert werden können. In diesem Zusammenhang führt Simon das Konzept der prozeduralen Rationalität ein (s. hierzu und zu Folgendem grundlegend u.a. Newell/Simon 1972, 3, 53ff., 72, 79, 824; Simon 1978c; 1978b; 1992; 1993b; 1999a).[8] Dieses Konzept beinhaltet die Grundlagen des iterativen Prozesses von Situationswahrnehmung, Entscheidungsgenerierung, Handlungsausführung und Habitualisierung. Die prozedurale Rationalität erfasst hierzu diejenigen kognitiven Beschränkungen, welche der Definition der beschränkten Rationalität zu Grunde liegen, und darüber hinaus diejenigen Aktionspotentiale, die es Akteuren ermöglichen, trotz der Beschränkungen zielorientierte ökonomische Entscheidungen zu fällen und Handlungen zu realisieren – und Innovationen zu generieren.

Ein prominenter Aspekt der prozeduralen Rationalität ist das Konzept des Anspruchsniveaus[9] als Alternative zum Nutzen- bzw. Gewinnmaximierungskonzept der Standardökonomik (s. hierzu und zu Folgendem grundlegend Simon 1955; 1964; 1972; 1988b; s. auch Cyert/March 2001, 162f., 172; March/Simon 1993, 170, 204). Nach Auffassung der SCP bilden prozedural rationale Akteure auf Basis des ihnen zugänglichen Wissens und ihrer Erfahrungen eine gewünschte Zielausprägung (d.h. ein Anspruchsniveau) in einem realistisch erscheinenden Ausmaß unter Berücksichtigung der Zielerreichung von Dritten (für den Satisfizierer relevante

[7] Die Komplexität von Umfeldzuständen manifestiert sich nach Simon u.a. in einer unübersehbaren Vielzahl von für eine Entscheidungssituation relevanten Variablen und Restriktionen sowie in Nichtlinearitäten der Zusammenhänge zwischen Variablen (s. Simon 1987; 1972, 169ff.).

[8] Simon rekurriert in diesem Zusammenhang explizit nicht auf das ökonomische Rationalitätsmodell, sondern auf das psychologische und bezieht sich hierbei auch auf den Psychologen William James (1952/1890), welcher den Begriff ‚Rationalität' als Synonym für logische Denkprozesse verwendet (s. Simon 1982, 426f.).

[9] Die SCP bezieht sich hier wieder auf die Psychologie, insbesondere auf Kurt Lewin und seine Forschungsgruppe (Lewin et al. 1944; s. hierzu z.B. Simon 1959, 262f.; 1978a, 356; 1979, 503).

Akteure bzw. Referenzgruppen). Sofern eine Handlung dann zu einem entsprechend zufriedenstellenden Ergebnis führt, gilt das Ziel als ‚satisfiziert'. Dabei wird zum einen angenommen, dass ein anfänglich definiertes Anspruchsniveau relativ gering ist und mit der Realisierung der erwünschten Zielhöhe bei Wiederholungen entsprechender Handlungen sukzessive ansteigt.[10] Sofern Ziele nicht erreicht werden, kann zum anderen auch ein Absenken des Anspruchsniveaus auf ein Niveau erfolgen, welches eher realisierbar erscheint.

Weitere relevante Aspekte der prozeduralen Rationalität sind (a) das Routine-, (b) das Problemlösungshandeln, sowie (c) die Lernfähigkeit von Akteuren und (d) das Erschließen von komplementären Ressourcen durch kollektive Lern- und Problemlösungsprozesse (s. grundlegend Simon 1990a; 1991a).

Ad (a) Routinehandlungen[11] ermöglichen es Akteuren, Entscheidungen zu treffen und Handlungen zu vollziehen, ohne aufwendige kognitive Leistungen zu erbringen. Sie schaffen auf diese Weise (kognitive) Freiräume für die Bearbeitung neuer Situationen:

> „Habit performs an extremely important task in purposive behavior, for it permits similar stimuli or situations to be met with similar responses of reactions, without the need for a conscious rethinking of the decision to bring the proper action. Habit permits attention to be devoted to the novel aspects of a situation requiring decision." (Simon 1997c, 100; s. auch u.a. Simon 1986a, 14; Cyert/March 2001, 120ff.)[12]

Ad (b) Das Problemlösungshandeln ist als Gegenpart des Routinehandelns zu verstehen: Es ist in Situationen erforderlich, für die keine Routinen vorliegen (s. grundlegend Newell/Simon

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[10] Cyert und March (2001, 172) formalisieren dies in Bezug auf die Bildung des Anspruchsniveaus von Unternehmen wie folgt: $G_t = a_1G_{t-1} + a_2E_{t-1} + a_3C_{t-1}$. Wobei G_t die aktuell erwünschte Zielausprägung (das Anspruchsniveau) eines Zieles darstellt, E_{t-1} die Erfahrungen der Organisation in der vergangenen Periode und C_{t-1} die beobachteten Erfahrungen der Wettbewerber in der vergangenen Periode. Die Parameter a_1 und a_2 stellen die Adaptionsgeschwindigkeit dar, a_3 gewichtet die Beobachtungen der Erfahrungen von Wettbewerbern und bildet die diesbezügliche Sensitivität ab.

[11] Simon und seine Kollegen verwenden verschiedene Begriffe für den Sachverhalt der Routine. Neben der Bezeichnung Gewohnheit wird auch von habituellem bzw. intuitivem Handeln (s. Simon 1992, 11; Simon 1997c, 100, 132) und mit Blick auf die Routinehandlungen von Unternehmen von einem Programm (s. March/Simon 1993, 160ff.) und/oder von „standard operating procedures" (Cyert/March 2001, 120) gesprochen.

[12] Neben der positiv konnotierten Entlastungsfunktion beinhalten Routinen aber auch negative Aspekte. Insbesondere in Situationen, in welchen das Handeln auf die Durchführung von neuen Aktivitäten ausgerichtet sein sollte, kann das Beharren auf Routinen dazu führen, dass entsprechende Suchaktivitäten nicht realisiert werden (s. March/Simon 1993, 194f.; Simon 1986, 17).

1972; Langley et al. 1987; Cyert/March 2001, 169; March/Simon 1993, 161ff., 195; s. auch Daskalakis 2002, 19ff.).[13] Mit dem Konzept des Problemlösungshandelns erfasst die SCP diejenigen (kognitiven) Grundlagen und (kognitiven) Prozesse, die zur Erschließung von neuen Handlungspotentialen und zur Durchführung neuer Handlungen führen. Diese Prozesse beginnen mit einer Problemwahrnehmung und enden mit einer Problemlösung oder auch mit Abbruch des Prozesses. Hierbei kann, u.a. in Abhängigkeit davon, ob ein genaues Ziel spezifiziert ist oder nicht, zwischen wohldefinierten und schlecht definierten Problemlösungsprozessen unterschieden werden. Letztere erfordern Problemfindungs- und Problemdefinitionsprozesse, welche dem ‚eigentlichen' Problemlösungsprozess vorgelagert sind (s. Simon 1988b, 7ff.; 1999b, 675). Die Generierung von Innovationen ist aus der Sicht der SCP als eine spezielle Klasse von Problemlösungsprozessen zu verstehen (s. March/Simon 1993, 195; Prietula/Simon 1989,123 auch Cyert/March 2001, 169).

Ad (c) Die Lernfähigkeit wird definiert als „(…) any change in a system that produces a more or less permanent change in its capacity for adapting to its environment" (Simon 1996, 100, s. auch zu Folgendem ebd.). Lernen erfolgt in einer sich verändernden Umwelt insofern stetig, dabei werden neue Gedächtnisinhalte aufgenommen und bestehende an die Erfahrungen angepasst (s. auch Newell/Simon 1958, 61). In diesem Sinne stellt Lernen eine Adaption des Langzeitgedächtnisses dar und ermöglicht es prozedural rationalen Akteuren, in Abhängigkeit von der individuellen Ausstattung mit kognitiven Fähigkeiten und den Umfeldbedingungen die kognitiven Kapazitäten zu erweitern (s. auch Simon 1978, 504; 1990, 16; 1996, 16).[14]

Ad (d) Das Ausmaß der individuellen Lern- und Problemlösungsfähigkeit ist dabei nicht nur von der individuellen Ausprägung kognitiver Faktoren geprägt, sondern auch von den (sozia-

[13] Im Rahmen von Problemlösungs- bzw. Problemfindungsprozessen können sich auch Problemlösungsschritte ergeben, für welche bereits Lösungspatterns (im Sinne von Routinen) zur Verfügung stehen (s. Newell/Simon 1972, 94ff.); spiegelbildlich können sich auch im Rahmen von Routinehandlungen neue Problemfelder ergeben, die Problemlösungs- bzw. Problemfindungsprozesse erfordern (s. auch March/Simon 1993, 160); insofern sind Routine- und Problemlösungshandeln nicht nur als dichotome Prozesse, sondern auch als ineinandergreifende Prozesse zu verstehen.

[14] Lernprozesse und Problemlösungs- bzw. Problemfindungsprozesse sind wieder als ineinandergreifende Prozesse zu verstehen. So können Lernprozesse notwendig sein und stattfinden, wenn bestehende Heuristiken auf Grund der Erfahrung im Problemlösungs- bzw. Problemfindungsprozesse verändert werden (s. Newell et al. 1958, 65; Simon 1996, 100ff.). Auch Routinehandlungen basieren letztendlich auf vorangegangenen Lernprozessen (s. Simon 1987, 16; 1990, 8).

len) Umfeldbedingungen, welche sich u.a. durch die Interaktion mit anderen Akteuren mit komplementären Eigenschaften bzw. mit komplementärem Wissen manifestieren. Allerdings ist festzustellen, dass derartige kollektive Prozesse im Werk der SCP zwar thematisiert werden, aber relativ unkonkret bleiben. So stellen Okada/Simon (1997) zwar fest, dass kollektive Problemlösungsprozesse auf Grund von Heterogenität der beteiligten Akteure zu besseren Ergebnissen führen können, u.a. weil der kognitive Suchraum erweitert wird, aber die Autoren betrachten dabei nicht die derartigen Situationen zu Grunde liegende soziale Interaktionsebene. Entsprechendes findet sich jedoch in einem anderen Argumentationsstrang von Simon, der nachfolgend kurz skizziert werden soll.

Für Simon sind, und dies formuliert er wieder in expliziter Abgrenzung zum traditionellen Akteurskonzept, Akteure grundsätzlich nicht als isolierte Entitäten zu verstehen, sondern auch in ihrer sozialen Interaktion mit dem Umfeld zu betrachten (s. hierzu und zu Folgendem Simon 1946; 1967; 1990b; Newell/Simon 1972, 3, 53ff., 72, 79, 824). Akteure sind demnach in ein sozio-kulturelles Milieu eingebettet, welches sowohl Handlungen begrenzt (etwa durch Normsetzung) als auch auf Genese und Ausprägung individueller Merkmale wie Fähigkeiten und Wissen und damit auf die individuelle Entwicklung wirkt. Dabei wird davon ausgegangen, dass Akteure danach streben, sich an ihr Handlungsumfeld zu adaptieren und hierbei durch die eigenen Aktivitäten das Handlungsumfeld prägen. Voraussetzung hierfür ist nach Simon eine spezifische Eigenschaft, die soziale Einfügungsbereitschaft[15], und altruistisches Handeln (s. hierzu und zu Folgendem grundlegend Simon 1983, 37ff., 1990b; s. Simon 2001, 83; Simon 1996, 44f.; s. auch Knudson 2003). Simon nimmt an, dass sich die soziale Einfügungsbereitschaft im Rahmen von evolutionären Prozessen herausgebildet hat, da Gruppen, deren Akteure eine derartige Eigenschaft aufweisen, gegenüber Gruppen, deren Akteure diese Eigenschaft nicht aufweisen, im Vorteil sind. Dieser begründet sich dadurch, dass die soziale Einfügungsbereitschaft die Realisierung von kollektiven Lernprozessen ermöglicht, welche sowohl die Fitness der jeweiligen Gemeinschaft als auch des jeweiligen Individuums stärken können.

[15] Übersetzung der Autorin; im Original zumeist „docility“ (s. Simon 1990; s. Simon 2001, 83; Simon 1996, 44f.) bzw. auch „susceptibility“ (s. Simon 1997a, 41).

Die soziale Einfügungsbereitschaft ist in diesem Sinne als ein Teilbereich der prozeduralen Rationalität anzusehen, weil Akteure hierdurch in die Lage versetzt werden, Aktionen durchzuführen, zu denen sie alleine nicht die Möglichkeit hätten. Im Werk von Simon findet sich jedoch keine weitere Konkretisierung der Thematik in Bezug auf Problemlösungsprozesse bzw. auf Innovationen, sodass die Frage der Wirkung der sozialen Einbettung eher unverbunden zum Gesamtwerk steht.

2.1.2.2. Das Konzept des innovierenden Unternehmens im Speziellen

Die im Abschnitt 2.1.2.1 dargestellten Grundlagen des Akteurskonzeptes werden im Rahmen der SCP auch auf das Handeln und Entscheiden von Unternehmen bezogen. Hierbei erfolgen jedoch einige Spezifikationen, u.a. in Bezug auf die Zielsetzungen von Unternehmen und auf die Aktionspotentiale, die sich durch die Verteilung der Aufgaben in Unternehmen und das Zusammenspiel (heterogener) Akteure ergeben. Dabei wird davon ausgegangen, dass in Unternehmen Subgruppen bzw. Einzelakteure zu identifizieren sind, die als relevante Träger der Unternehmenszielsetzung und entsprechender Unternehmensentscheidungen anzusehen sind (s. Cyert/March 2001, 31) – dies erst ermöglicht im Kern die Erfassung der Unternehmung als handelnder und entscheidender Entität.[16] Dabei wird vorausgesetzt, dass prozedural rationale Unternehmen zielorientiert und in Interaktion mit ihrer Unternehmensumwelt handeln und sich durch Lernen, Innovation sowie Veränderung von Zielen und Zielausprägungen an neue Umstände adaptieren müssen, um am Markt zu bestehen (s. grundlegend Levinthal/March 1981; Simon 1993a; s. hierzu und zu Folgendem auch Daskalakis 2011b, 176ff.).[17]

In der SCP wird zwischen zwei Arten von Unternehmenszielen unterschieden. Dies sind zum einen aggregierte, konstitutive Oberziele wie Umsatz, Gewinn, Profit, Absatz, Unterneh-

[16] In diesem Sinne beziehen sich Simon und seine Mitautoren häufiger auf das Handeln und Entscheiden von Managern als pars pro toto der Unternehmung als Ganzes (s. March/Simon 1993, 171; Simon 1946, 56ff.; Simon 1997c, 182ff.)

[17] Neben dem im Folgenden hier thematisierten Innovationshandeln fokussiert sich die SCP auch auf andere Aspekte des Handelns und Entscheidens von und in Unternehmen, u.a. auf den konfliktbehafteten Zusammenhang zwischen Individualzielen und Unternehmenszielen und dessen Lösung, die „quasi resolution of conflicts“ (Cyert/March 2001, 164), sowie auf die Motivation von Mitarbeitern, in Unternehmen zu verbleiben (March/Simon 1993, 103ff.); da diese Sachverhalte für die vorliegende Fragestellung nicht von vorrangiger Bedeutung sind, wird hierauf im Folgenden nicht eingegangen.

mensgröße, Marktanteil und Zufriedenstellung von Kundenbedürfnissen und zum anderen operative Ziele, die die konkrete Umsetzung der Oberziele beinhalten (s. Cyert/March 2001, 39f., 164f.; Simon 1964, 6; 1997c, 5, 143f.). Als relevante Umfeldänderungen werden u.a. von Unternehmen nicht zu kontrollierende „external shocks" (Cyert/March 2001, 118) genannt sowie Anforderungen der Gesetzgebung (s. ebd. 46; 206f.).

Die SCP nimmt dabei eine grundlegende Differenzierung von Innovationsprozessen vor, welche bislang in der Literatur kaum rezipiert wurde bzw. wenn, dann ohne Bezug auf die beiden Autoren verwendet wird (s. z.B. Damanpour 1996, 699[18]; Rogers 1995[19], 398). Sie unterscheidet zwischen einerseits den Prozessen, die zur Entscheidung zur Innovation führen, und andererseits der Durchführung von Innovationen. Ersteres ist im „Concept of Initiation" (March/Simon 1993, 193ff.) erfasst, Letzteres bezieht sich auf Problemlösungsprozesse im in Abschnitt 2.1.2.1 genannten Sinne. Die beiden Prozesse sind nach der SCP in der Struktur einer Unternehmung auf verschiedenen Ebenen verortet: Der Initiierungsprozess wird auf der obersten Unternehmensebene realisiert und ist als strategische Entscheidung zu verstehen, die Innovation selbst wird von den jeweils relevanten nachgelagerten Subelementen umgesetzt. Ein Initiierungsprozess ist in diesem Sinne der tatsächlichen Durchführung einer Innovation zeitlich vorgelagert.

Ausgangspunkt des ‚Concept of Initiation' ist die (durch die beschränkte Rationalität begrenzte) Beobachtung von internen Prozessen und Umfelddeterminanten (s. hierzu und zu Folgendem March/Simon 1993, 194f., 212f.; Simon 1993a, 131, 134). Sofern hierbei ein Problem wahrgenommen wird, welches die aktuell vorhandenen Unternehmensziele sowie deren Ausprägung im Sinne des Anspruchsniveaus als gefährdet erscheinen lässt, bzw. einer Realisierung bereits im Wege stand, und zu dem im bestehenden Handlungsrepertoire keine Problemlösungsstrategie identifiziert werden kann, beginnt die Initiation. Diese wird als Prozess angesehen, welcher die Analyse des wahrgenommenen Problems, die Suche nach Problemlösungsstrategien (Innovationen), die aus dem Problem resultierende Zielbildung bzw.

[18] Autoren, welche die Initiation thematisieren, finden sich, wie auch Damanpour (welcher sich auf das 2-Phasen-Modell von Rogers bezieht), eher in der Management- bzw. der Organisationsforschung (s. z.B. Daft 1978; Glynn 1996; Rice et al. 2001).

[19] Rogers 2-Phasen-Modell differenziert wie die SCP zwischen der Initiierung und der Implementierung einer Innovation; auch die weitere Differenzierung der Phasen ähnelt dem Konzept der SCP (s. Rogers 1995, 389ff.).

auch die Respezifikation vorhandener Ziele sowie die Evaluierung von alternativen Vorgehensweisen beinhaltet. Den Abschluss der Initiation bildet dann die (strategische) Entscheidung für oder gegen eine Innovation. Bei der Ablehnung der Innovation verbleiben die Unternehmen im Routinemodus und es erfolgt eine Anpassung des Anspruchsniveaus der Unternehmensziele. Sofern eine Entscheidung für die Innovation fällt, umfasst der Initiierungsprozess auch die Verteilung der jeweils notwendigen Aufgaben entsprechend der Unternehmensstruktur.[20]

Hinsichtlich der Durchführung von Innovationen in Unternehmen unterscheidet die SCP zwei Arten von Problemlösungsprozessen: das produktive bzw. explorative sowie das reproduktive bzw. exploitative Problemlösen (s. hierzu und zu Folgendem grundlegend March 1988, 11; 1994, 42ff., 237; March/Simon 1993, 197ff.). Das produktive Problemlösen realisiert sich in schlecht strukturierten Problemräumen, zu deren Bearbeitung neue Lösungen mit neu zu kreierenden Lösungskomponenten geschaffen werden müssen. Produktive Problemlösungsprozesse sind in diesem Sinne als Prozesse der Erstellung (mehr oder weniger) radikaler Innovationen zu verstehen. Das reproduktive Problemlösen hingegen bezieht sich auf Problemlösungsprozesse, die auf Basis des bestehenden Wissens- und Informationsstocks bzw. der Fähigkeiten von Unternehmen durchgeführt werden können. Diese Art von Problemlösungsprozessen können insofern auch als Prozesse der Erstellung von inkrementellen Innovationen angesehen werden.[21]

Eine weitere Unterscheidung von Innovationsarten wird noch in Verbindung mit der Unter- bzw. Übererfüllung des Aspirationsniveaus und einem spezifischen Konzept der SCP themati-

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[20] Als Innovationsarten werden sowohl Produktinnovationen als auch Prozess-, Marketing-, Organisations- und Finanzierungsinnovationen genannt (s. March/Simon 1993, 210; Prietula/Simon 1989, 123). Dabei unterscheidet die SCP zumeist nicht explizit zwischen Invention und Innovation. Vielmehr werden diese beiden Begriffe, ebenso wie u.a. die Begriffe ‚design', ‚design of new products', ‚creative thinking' und ‚productive thinking' bzw. ‚search for new alternatives' sowie ‚change of program' häufig synonym verwendet (s. z.B. March/Simon 1993, 195f.; Newell et al. 1958, 1; Simon 1985, 19; 1991a, 131; 1995a, 3). Insofern ist davon auszugehen, dass Simon und seine Kollegen grundsätzlich, wie auch die vorliegende Arbeit, einen weiten Innovationsbegriff verwenden. Im Folgenden wird, außer bei wörtlichen Zitaten, der Begriff ‚Innovation' verwendet, auch dann, wenn im Originaltext einer oder mehrere der oben genannten anderen Begriffe verwendet werden.

[21] Im Rahmen des Innovationskonzeptes wird zudem die Imitation als dritte, den Neuheitsgrad einer Innovation charakterisierende Innovationsart angesprochen, allerdings ohne Zuordnung zu Problemlösungsprozessen (s. March/Simon 1993, 210; Simon 1993a, 133) und eher am Rande, ohne weitere theoretische Fundierung. Imitationen haben demnach den Vorteil, dass sie kostengünstiger sind, sowohl hinsichtlich der Entwicklungskosten selbst als auch mit Blick auf das Risiko der Fehleinschätzung und der hieraus resultierenden pekuniären Effekte.

siert, dem Konzept des organisationalen Slacks (s. hierzu und zu Folgendem in diesem Absatz grundlegend Cyert/March 2001, 41ff., 189ff.). Slack ist definiert als ein (kurzfristiger) Überschuss an monetären Ressourcen eines Unternehmens, welcher nicht konkret zur Erfüllung von Zielen des Unternehmens eingesetzt wird. Nach der SCP kann eine Übererfüllung eines Anspruchsniveaus dann dazu führen, dass ein vorhandener Slack für die Realisierung einer Innovation („sucess induced search“[22]; March 1994, 34; s. auch Cyert/March 2001, 189; Levinthal/March 1981, 309) verwendet wird, für welche keine unmittelbare Notwendigkeit besteht und welche eher in radikaleren Innovationen resultiert. Dem stehen Innovationen gegenüber, welche durch eine Unterschreitung des Anspruchsniveaus ausgelöst werden („failure-induced search“; March 1994, 34). Sie sind weniger radikal, aber zielorientierter und unmittelbarer an den Unternehmenszielen ausgerichtet (Cyert/March 2001, 188ff.; March/Simon 1993, 203).

Inwieweit und mit welchem Erfolg Innovationsprozesse initiiert und durchgeführt werden, hängt dann von den spezifischen Fähigkeiten und Merkmalen sowie von der jeweiligen Problemlösungssituation ab. Relevante Aspekte hierbei sind, neben der monetären Ressourcenausstattung, hinreichendes Wissen, Kreativität, die (intrinsische) Motivation zur Innovation sowie, hiermit verbunden, Neugierde und damit auch die Aufmerksamkeit, die der jeweiligen Innovation zugewendet wird (s. hierzu und zu Folgendem in diesem Absatz Simon 1985, 18f.; 1988b, 9; 1988a, 180ff.). Insbesondere im Initiierungsprozess sind zudem Eigenschaften wie die Fähigkeit, neue Chancen wahrnehmen und entsprechende Ressourcen mobilisieren zu können, sowie auch ganz allgemein Durchsetzungsfähigkeit und Risikobereitschaft und insgesamt die Einstellung gegenüber Innovationen von Bedeutung. Weiterhin wichtig ist die Befähigung zum strategischen Planen, d.h. die Fähigkeit, zukünftig relevante Trends und Entwicklungen erkennen zu können. March differenziert mit Blick auf die spezifischen Eigenschaften zudem zwischen dem explorativen und dem exploitativen Problemlösen. Ersteres erfordert Eigenschaften wie „[…] risk taking, experimentation, play, flexibility, discovery […]“ (March 1994, 237). Letzteres ist durch Merkmale wie „close attention, systematic reason, risk aversion, sharp focus ...“ (March 1999, 184) gekennzeichnet.

[22] Weitere diesbezügliche Begriffe sind „slack innovation“ (Cyert/March 2001, 189) und „slack search“ (Levinthal/March 1981, 309).

2.2. Aktuelle Diskussionsfelder der Innovationsforschung

2.2.1. Innovationsökonomik

Die Auseinandersetzungen von Veblen und Schumpeter mit dem Gegenstandsbereich der Innovation im Allgemeinen hatten zunächst wenig systematischen Widerhall in der ökonomischen Forschung. In den 50er Jahren des letzten Jahrhunderts jedoch begann, zunächst insbesondere in den USA (s. Godin 2010a)[23], eine systematische Auseinandersetzung mit dem Forschungsfeld Innovation, wobei hier die Invention im Fokus stand. Diese Auseinandersetzung war einerseits, aufbauend auf Abramovitz (1956) und Solow (1957), von der Erkenntnis motiviert, dass das wirtschaftliche Wachstum mit den traditionellen Annahmen der Ökonomik nicht zu erklären ist, sondern vielmehr Innovationen bzw. der technische Wandel zu berücksichtigen sind (s. Nelson 1959a, 102), und andererseits war sie von militärischen Anforderungen im Zuge des Kalten Krieges geprägt (s. Antonelli 2009, 614; Fagerberg/Verspagen 2009, 220ff.). Die Forschung war eher politikpraktisch und/oder empirisch ausgerichtet und in ihrem theoretischen Bezug eher an der Standardökonomik und weniger an der Entwicklung eines alternativen Theorieansatzes bzw. einer akteursbasierten Fundierung orientiert (s. aber z.B. MacKinnon 1964; Rossman 1931; Usher 1959; mit Blick auf das Innovationsverhalten von Konsumenten auch Katona 1960). Entsprechend ist auch die Bezugnahme zur SCP relativ gering ausgeprägt, obwohl diese und die relevanten Autoren der damaligen Innovationsökonomik nahezu gleichzeitig zu publizieren begannen.

Die mangelnde Ausrichtung auf eine alternative theoretische Fundierung wurde von Nelson bereits 1962 in der Einleitung des Sammelbandes zu der im Jahre 1960 durchgeführten und für die Innovationsökonomik grundlegenden Konferenz des National Bureau of Economic Research (NBER) „The Rate and Direction of Inventive Activity: Economic and Social Factors“ kritisch kommentiert. Nelson merkt an, viele der Beiträge seien „attempts to analyze inventive activity with the traditional tools of economics“ (Nelson 1964, 8). Er verweist unter Bezugnahme auf zwei Beiträge des Sammelbandes, die sich mit dem inventiven Akteurshan-

[23] Siehe zur Entwicklung der Innovationsforschung in Europa, insbesondere auch zur Rolle der Science Policy Research Unit (SPRU) an der Universität von Sussex in England Fagerberg (2003, 17); Fagerberg/Verspagen (2009); Godin (2010b). Die SPRU war auf eine interdisziplinäre Forschung ausgerichtet, ihr erster Direktor war Freeman und einige der namhaften Innovations- bzw. Evolutionsökonomen wie Dosi und Soete waren hier tätig.

deln befassen (Machlup 1964; Kuznets 1964), weiterführend darauf, dass die traditionelle Ökonomik nicht geeignet sei, Unterschiede im Inventionshandeln in Bezug auf die Kreativität und Produktivität von Inventoren zu erklären, und hier insofern zur ökonomischen Analyse von Inventionen dringend Befunde aus der Psychologie und der Soziologie benötigt würden (Nelson 1964, 8). Korrespondierend hierzu lässt sich feststellen, dass die Konferenzbeiträge die SCP nicht berücksichtigen, dabei waren zumindest zwei der drei Hauptwerke sowie auch weitere Aufsätze bereits publiziert. So bezieht sich keiner der Aufsätze zur Konferenz auf das Konzept der beschränkten Rationalität und es finden sich nur drei kurze Referenzen auf Simon, ein Verweis in dem Aufsatz von Merrill (1964, 434), welcher sich auf das hierarchische Konzept der Organisation bezieht, und je ein Verweis von Nelson (1964, 551) und von Griliches (1964, 353) hinsichtlich des Entscheidungshandelns bzw. des Entscheidens unter Unsicherheit.

Bereits auf der oben genannten NBER-Konferenz wurden viele heute noch relevante Aspekte der Innovationsforschung aufgegriffen, etwa die Bedeutung von bestehendem (technologischem) Wissen bzw. vorhandenen Informationen, die Probleme der Prognostizier- und Appropriierbarkeit und das resultierende Externalitätenproblem (z.B. Arrow 1964; Merrill 1964; Schmookler 1964) sowie die Probleme der Indikatorik (Kuznets 1964; Sanders 1964). Analysiert wurde auch die Relevanz öffentlicher Forschung, der Einfluss der Nachfrage, der Einfluss der technologischen Gegebenheiten sowie des sozioökonomischen Umfeldes auf die Entstehung und Verbreitung von Inventionen sowie die Bedeutung von Aspekten wie räumlicher Nähe, Sektoralstruktur und Unternehmensgröße (s. z.B. Arrow 1964; Klein 1964; Machlup 1964; Markham 1964; Marshall/Meckling 1964; Merrill 1964; Schmookler 1964; Siegel 1964; Thompson 1964; Worley 1964).

Umfang und Analysespektrum der Innovationsökonomik haben sich seit der NBER-Konferenz erheblich weiterentwickelt. Eine Vielzahl von fachspezifischen Publikationen und dabei auch eine erhebliche Reihe von empirischen Untersuchungen zeugen von der heutigen Relevanz des Forschungsfeldes (s. zu einer Übersicht Fagerberg/Verspagen 2009). Die empirische Orientierung ist dabei als ein wesentlicher Beitrag in Richtung einer Ökonomik zu verstehen, die sich an realen Sachverhalten und nicht an abstrakten Konzepten orientiert. Hervorzuheben als neue Beiträge sind u.a. das rückgekoppelte Innovationsmodell von Kline/Rosenberg (1986), die Auseinandersetzung mit Rolle und Wirkung von nationalen und/oder regionalen

Innovationssystemen (s. z.B. Cooke 1992; Lundvall et al. 2002; Nelson 1993; s. zu einer Übersicht Godin 2010c) und, auch hiermit verbunden, die Beschäftigung mit der Bedeutung und den Determinanten von Innovationskooperationen bzw. Innovationsnetzwerken (s. z.B. Burt 1980; Fritsch 2005; Granovetter 1985; Pyka 2011; Tödtling et al. 2009) sowie die Einbeziehung von hierfür relevanten verhaltensbezogenen Faktoren wie z.B. Vertrauen (s. z.B. Bidault/Castello 2010; Noteboom 2011; Powell et al. 1996). Ein relativ junges Forschungsfeld ist hierbei auch die Analyse von Umweltinnovationen (s. z.B. Horbach et al. 2012; Jaffe et al. 2003; Rennings 2000).

Allerdings lässt sich feststellen, dass die Kritik Nelsons an den Beiträgen der oben genannten NBER-Konferenz von 1960 auch heute noch partiell aktuell ist. Nelson (2012a, 40f.) thematisiert dies in seiner Einführung zu einem Sammelband anlässlich des 50-jährigen Jubiläums der NBER-Konferenz und unterscheidet in diesem Zusammenhang grundlegend zwei Ansätze der modernen Innovationsökonomik (Nelson spricht von ‚camps'): Einerseits (Innovations-)Ökonomen, welche sich überwiegend an der Standardökonomik orientieren, „shying away from saying explicitly that the microeconomics theory of the textbooks does not work very well with the subject matter they are addressing" (Nelson 2012a, 41); andererseits (Innovations-)Ökonomen, welche stärker an einer alternativen Theorieentwicklung und Akteursbasierung orientiert sind. Zu den Letzteren sind insbesondere die von Nelson und Winter (1982) inspirierte Evolutionsökonomik bzw. die Neo-Schumpeterian Economics[24] zu zählen. Ergänzend ist noch eine dritte, von Nelson nicht thematisierte Gruppe zu nennen, die Innovationsökonomen erfasst, welche nicht zwangsläufig mit der Standardökonomik konform gehen, jedoch nicht explizit an einer Theorieentwicklung orientiert sind, sondern mehr an einer politikpraktischen Evaluierung. Im Rahmen der vorliegenden Fragestellung interessiert hier die evolutionsökonomische Perspektive. Bevor Abschnitt 2.2.2 sich dieser Perspektive widmet, soll noch auf einen spezifischen Aspekt der eingeschränkten theoretischen Fundierung eingegangen werden, nämlich deren Folgen für die Ergebnisse der empirisch fundierten Innovationsökonomik.

[24] In der vorliegenden Arbeit soll nicht auf die unterschiedlichen Auffassungen über die Gegenstandsbereiche und den Zusammenhang von Evolutionsökonomik und Neo-Schumpeterian Economics eingegangen werden. Zu den unterschiedlichen Positionen kann auf Witt (2008a) und Hanusch/Pyka (2007) verwiesen werden (s. auch die Anmerkung in Nelson/Winter 1982, 39); im Folgenden wird verallgemeinernd der Begriff ‚Evolutionsökonomik' verwendet und hierunter werden auch die ‚Neo-Schumpeterian Economics' subsumiert.

Die empirische Innovationsökonomik ist, wie oben angesprochen, ein wichtiger Beitrag zu einer realitätsnahen Ausgestaltung der Ökonomik, d.h. im vorliegenden Kontext zu einem realitätsnahen Verständnis der akteursbasierten Grundlagen des ökonomischen Wandels. Allerdings ist festzustellen, dass die empirische Innovationsökonomik traditionell eher leicht zu erhebende Indikatoren wie etwa die Indikatoren zur Forschung und Entwicklung (F&E), die Unternehmensgröße und die Patentdaten verwendet, obwohl schon länger bekannt ist, dass die Verwendung dieser Indikatoren, insbesondere der F&E- und der Patentindikatoren, je nach Untersuchungszusammenhang problematisch sein kann[25] (s. zu einem kritischen Überblick über die Entwicklung der Innovationsindikatorik Godin 2002; 2011).[26] Weniger diskutiert und verwendet werden alternative Indikatoren und insbesondere auch nicht solche Indikatoren, welche eine Evaluierung im Sinne einer akteursbasierten Fundierung ermöglichen – dies korrespondiert mit der mangelnden theoretischen Fundierung bzw. mit der theoretischen Ausrichtung der Innovationsökonomik. Diese Fokussierung schränkt das Blickfeld auf den zu untersuchenden empirischen Erkenntnisgegenstand ein und begrenzt damit auch die Hypothesenbildung und die überhaupt zu erreichenden Ergebnisse. Hiermit mag sich dann auch der Befund von Cohen (2010, 193ff.) erklären, welcher nach einer umfangreichen Sichtung der Ergebnisse der empirischen Innovationsökonomik feststellt, dass diese teilweise widersprüchlich sind und die Untersuchungen sich zu wenig auf die Unternehmensebene ausrichten. Cohen zieht diesbezüglich folgenden Schluss:

> „Perhaps one of the more basic lessons to emerge from the empirical literature is that, although testing loosely motivated hypotheses may yield empirical results, even robust ones, their interpretation can be challenging, and the insight that can be gleaned from

[25] So kann beispielsweise mit den klassischen F&E-Indikatoren (Umsatzanteil für F&E-Aktivitäten, Anteil der F&E-Beschäftigten) das Innovationsverhalten von kleineren und mittleren Unternehmen ohne ausgewiesene F&E-Abteilung nicht oder nur bedingt erfasst werden; weiterhin bildet der Patentindikator, beispielsweise aufgrund von (Nicht-)Patentierungsstrategien und der Ausblendung von Sektoren, welche nicht patentierungsfähige Produkte erstellen, nur einen Teilbereich der Innovationsleistungen ab (s. grundlegend Archibugi/Planta 1996; Griliches 1990; Grupp 1998, 161ff.; Kleinknecht et al. 2002; Pavitt 1985).

[26] Standardwerke der Innovationsindikatorik sind das ursprünglich aus den 60er Jahren stammende Frascati-Manual (OECD 2002), welches insbesondere auf die Erhebung von Daten im Zusammenhang mit der Forschung und Entwicklung zielt (s. hierzu ausführlicher Godin 2008), und das in den Abschnitten 1 und 2.2.1 erwähnte OLSO-Manual (OECD/Eurostat 2005), welches zwar auch aktuelle Aspekte wie die Relevanz von Kooperationen etc. aufnimmt, aber trotz der Bezugnahme auf die Unternehmensebene keine Akteursbasierung im Sinne der vorliegenden Arbeit vornimmt.

such findings is often limited in the absence of underlying theory. […] Indeed, even very simple theory can radically revise the interpretation of what may appear to be the most straightforward of empirical relationships, such as that between R&D productivity and firm size.“ Cohen (2010, 198)[27, 28]

Sofern Cohen und Nelson gefolgt wird, ist im Sinne des vorliegenden Erkenntnisgegenstandes insgesamt festzustellen, dass der (empirischen) Innovationsökonomik eine akteurstheoretische Einbettung fehlt und somit insbesondere auch die Potentiale, die aus einer empirischen Ausrichtung für die Entwicklung einer alternativen Theorie entstehen, nicht erschlossen werden. Eine auf die SCP rekurrierende empirische Ausrichtung würde dabei zum einen eine empirische Analyse auf Akteursebene, d.h. beispielsweise direkt in Unternehmen voraussetzen, und zum anderen eine Herangehensweise erfordern, welche die Erfassung von komplexeren kausalen Zusammenhängen ermöglicht. Dies impliziert die Verwendung von entsprechenden statistischen Methoden und stellt relativ hohe Anforderungen an die Ausgestaltung von empirischen Untersuchungen und korrespondierenden Indikatoren.

2.2.2. Evolutionsökonomik

Obwohl, wie in Abschnitt 2.2.1 dargestellt, die Innovationsökonomik seit den 50er Jahren umfangreiche Forschungsleistungen erbracht hat, lässt sich feststellen, dass eine systematische Auseinandersetzung mit dem Erbe von Schumpeter und Veblen einerseits sowie der Inkorporation der SCP als relevantem Konzept des Akteurshandelns andererseits im Wesentlichen erst durch das Werk ‚An Evolutionary Theory of Economic Change‘ von Nelson und Winter (1982) initiiert wurde.[29] Die beiden Autoren beschäftigten sich nicht nur mit aktuellen Erkenntnissen der Innovationsökonomik, sondern verstanden ihren Ansatz *erstens* explizit als

[27] Zu berücksichtigen ist hier aber, dass Cohen nicht zwischen den beiden von Nelson identifizierten ‚Lagern‘ differenziert. Sein Befund ist auf die empirische Innovationsforschung im Allgemeinen bezogen und ein Blick auf die Literaturverweise zeigt, dass das auch Autoren einschließt, die dem zweiten Lager zuzurechnen sind.

[28] Verhaltensbasierte empirische Untersuchungen zum Gegenstandsbereich der Innovation finden sich u.a. auch in der Konsumenten-, Management- und Organisationsforschung. Allerdings ist auch hier im Sinne von Nelson bzw. Cohen festzustellen, dass diese Forschungsbereiche eher Einzelaspekte betrachten (s. z.B. Jansson 2011; Martín-Peña et al. 2010; Oerlemans/Pretorius 2008; Sawang/Unsworth 2011) und weniger auf die Entwicklung eines Akteurskonzeptes bzw. eines allgemeineren theoretischen Rahmens abzielen.

[29] Veblen wird allerdings in Nelson und Winter (1982) nicht explizit aufgeführt.

Alternativmodell zu den standardökonomischen Annahmen über das Akteurs- und Unternehmensverhalten sowie die Grundlagen des wirtschaftlichen Wachstums, wobei *zweitens* die alternative Mikrofundierung wesentlich auf dem Konzept der beschränkten Rationalität von Simon sowie dem hierauf aufbauenden Unternehmensverhaltenskonzept der Carnegie-School beruhte. Nelson und Winter entwickelten dabei *drittens* einen theoretischen Rahmen, der das biologische Evolutionsmodell auf die Handlungen von Organisationen und die wirtschaftliche Entwicklung, d.h. die Entwicklung von Industrien, bezieht. Routinen repräsentierten dabei die ‚Gene', d.h. das Gedächtnis von Unternehmen, und Veränderungen von Routinen (Innovationen) gelten als ‚Mutationsprozesse'. Der Markt stellt das (unsichere und dynamische) Selektionsumfeld dar, an welchem sich die Profitabilität von Unternehmen misst. Die Autoren verbanden ihre konzeptionellen Überlegungen *viertens* mit einer spezifischen Methode der Computermodellierung, den Multi-Agentensystemen (s. weiterführend zu den Modellen von Nelson und Winter Andersen 1994).

Nelson und Winter legten mit ihrem Ansatz einen wichtigen Grundstein für die Etablierung der Evolutionsökonomik als Forschungsfeld und regten eine Vielzahl von Publikationen an (s. zu einer Übersicht Cantner/Hanusch 2002; Silva/Teixeira 2009; s. auch Dolfsma/Leydesdorff 2010). Das langfristige Ziel der Evolutionsökonomik ist dabei nach Nelson und Consoli (2010, 666) die Entwicklung einer vollständigen Theoriealternative zur Neoklassik. Der zentrale Erkenntnisgegenstand der Evolutionsökonomik lässt sich nach Witt dabei wie folgt definieren:

> „An evolutionary theory is: (i) dynamic – such that the dynamics of the processes, or some of their parts, can be represented; (ii) historical – in that it deals with historical processes which are irrevocable and path-dependent; (iii) self-transformation explaining – in that it includes hypotheses relating to the source and driving force of the self-transformation of the system." (Witt 2002, 10)

Innovationen sind hierbei, im Sinne von Schumpeter und Veblen, die zentralen Veränderungskräfte des wirtschaftlichen Geschehens. Allerdings lässt sich feststellen, dass diese Definition zwar den Nukleus der Evolutionsökonomik charakterisiert, die Evolutionsökonomik selbst jedoch ein relativ heterogenes Forschungsfeld darstellt (s. Silva/Teixeira 2009; Witt 2008a; s. auch Buenstorf 2006). Witt (2008a) sieht sogar deutliche Anzeichen einer Desintegration durch die Unvereinbarkeit unterschiedlicher Ansätze.

Nach Witt (2008a) lassen sich diesbezüglich vier differierende Richtungen der Evolutionsökonomik identifizieren*: Erstens* die ‚Darwinisten', die sich auf das Konzept des ‚Universal Darwinism' beziehen, hierzu kann sicherlich prominent Hodgson gezählt werden, sowie *zweitens* die ‚Neo-Schumpeterianer' mit Nelson und Winter als Kernprotagonisten, in deren Fokus Aspekte des technologischen Wandels in Analogie zum evolutionsbiologischen Konzept stehen. *Drittens* führt Witt die ‚Naturalisten' an, die ein generisches Konzept der Evolution verfolgen, Entstehung und Verbreitung von Neuerungen (im Sinne eines erweiterten Innovationsbegriffes) im Fokus haben und sich mit einem Bündel von Gegenstandsbereichen (langfristige Entwicklung, institutionelle Evolution, Produktion, Konsumption, Wachstum und Nachhaltigkeit) beschäftigen. Spezifische Merkmale sind nach Witt u.a. die Bezugnahme auf die genetische Disposition der Akteure sowie auf die Interdependenz von ökonomischer Aktivität und ökologischer Wirkung. Witt führt hier als prominente Autoren Veblen, Georgescu-Roegen, Hayek und North an, er selbst ist sicherlich dieser Gruppe zuzuordnen. *Viertens* ist nach Witt der Ansatz von Schumpeter zu nennen, der wie die ‚Naturalisten' ein generisches Konzept der Evolution zu Grunde legt, jedoch ohne Bezugnahme auf ökologische Aspekte.

Die von Witt vorgenommene Systematisierung kann sicherlich kritisiert werden, u.a. ist zu fragen, ob sich der neo-schumpeterianische Ansatz tatsächlich derart stark an das biologische Evolutionsmodell anlehnt, wie von Witt dargestellt. So betont etwa Nelson (2012b, 295ff.), dass eine einfache Übertragung des biologischen Evolutionsmodells von ihm nicht vorgenommen würde und dies auch nicht möglich sei, weil das Markt- und Innovationshandeln von Akteuren immer auch zweckgerichtet und absichtsvoll sei (s. z.B. auch entsprechende Anmerkungen in Nelson und Winter 1982, 11; Winter 1971, 245f.).

Nach Auffassung der Autorin kann eine weitere Differenzierung evolutionsökonomischer Ansätze vorgenommen werden, die quer zu der Systematisierung von Witt liegt, nämlich die Differenzierung zwischen Ansätzen, welche im Sinne einer Theorieentwicklung die Vorlage von Veblen und Schumpeter aufnehmen und bei der Analyse der Relevanz von Innovationen für den wirtschaftlichen Wandel auch auf die Entwicklung eines realistischeren Akteurskonzeptes fokussieren. Tatsächlich betrachtet Nelson (2012b) - wie auch andere Autoren (s. z.B. Beckenbach 2001; Buenstorf 2012; Weise 1996; Witt 1987; s. auch unten) - die akteursbasierte Perspektive und Analyse als ein zentrales Element der Evolutionsökonomik:

„The treatment, or rather the treatments, of human cognition and behavior in evolutionary economics clearly are very different from how these subjects are treated in neoclassical economics. In the first place, evolutionary economics is committed to trying to ‚get the process right.' **The presumption is that understanding of how human actions are generated in particular contexts is an essential part of a theory that aims to explain or predict what those actions are.** The argument in neoclassical theory that economic agents behave ‚as if' they maximized utility, and it does not matter how they actually arrive at the actions they do, is not acceptable from this point of view." (Nelson 2012b, 7; Hervorhebung durch die Autorin)

Buenstorf spitzt dieses Argument zu folgender Aussage zu:

„Evolutionary economics is behavior economics – it studies the behavior of individual and organizations in economic contexts." (Buenstorf 2012, 1)

In einer so verstandenen Ausrichtung der Evolutionsökonomik steht der wirtschaftliche Akteur als treibende Kraft des wirtschaftlichen Wandels im Fokus und es wird, wie auch bei Veblen und Schumpeter, davon ausgegangen, dass sich Mikro- und Makroebene (sowie Mesoebene, s. Dopfer 2006) interdependent in einem rückgekoppelten Prozess wirtschaftlicher und innovativer Aktivitäten entwickeln.

Oben wurde bereits angeführt, dass sich Nelson und Winter (1982) im Rahmen ihres Konzeptes der wirtschaftlichen Evolution explizit auf die SCP fokussieren. Diese Bezugnahme, und hierbei insbesondere die Übernahme des Konzeptes der beschränkten Rationalität, kann als grundlegend zumindest für diejenigen Evolutionsökonomen angesehen werden, die eine solche akteursbasierte Perspektive verfolgen (s. z.B. Buenstorf 2012; Dequech 2001; Dopfer 2004; Dosi/Marengo 2007; Geisendorf/Weise 2001; Güth 2000; Morrison/Potts 2009; Pyka/Fagiolo 2007; Weise 1996; Witt 1987). Dies schließt auch Autoren wie Hodgson und Knudsen (s. z.B. Hodgson/Knudsen 2011) ein, welche auf das Konzept des ‚Universal Darwinism' bzw. des ‚Generalized Darwinism' rekurrieren. Im Folgenden sollen beispielhaft die Ansätze von Nelson und Winter, Dosi sowie Witt als Protagonisten einer verhaltensbasierten Perspektive skizziert werden.

Nelson und Winter (1982) beziehen sich nicht nur auf das Konzept der beschränkten Rationalität, sondern stellen einen der zwei Handlungsmodi des Konzeptes des Unternehmensver-

haltens der SCP in den Mittelpunkt ihres Akteurskonzeptes: das oben bereits erwähnte Routinehandeln. Innovationen sind zwar zentral für den Ansatz von Nelson und Winter, werden jedoch, im Gegensatz zum Unternehmensmodell der SCP, weniger als eigenständige Handlungsmodi, sondern eher als routinisierte Operationen angesehen (s. Nelson/Winter 1982, 133; s. auch Daskalakis 2002).[30] Die von Nelson und Winter ebenfalls thematisierte Relevanz des individuellen und organisationalen Wissens bzw. Lernens, beides Aspekte des Konzeptes der prozeduralen Rationalität, wird dann lediglich im Kontext der Frage, wie sich dieses zu organisationalen Routinen verhält bzw. zu deren Genese beiträgt, diskutiert (s. hierzu auch Buenstorf 2012, 3). Dies entspricht nicht der Differenzierung zwischen den beiden Handlungsmodi, wie sie die SCP vorgenommen hat (s. kritisch zur Fokussierung auf die Routine bei Nelson und Winter auch Foss 2003, 248ff.; Gavetti et al. 2007, 524; Witt 2001, 3f.; 2011, 161).[31] Weiterhin wird die Frage der Entscheidung zur Generierung von Innovationen relativ einfach gefasst und höchstens an den Satisfizierungsgrad geknüpft. Das Innovationskonzept bzw. insbesondere auch das Initiationskonzept der SCP wird, obgleich die entsprechenden Standardwerke zitiert werden, nicht weiter aufgenommen (s. zu einer kritischen Diskussion der Rezeption der Carnegie-School bzw. des Konzeptes der beschränkten/prozeduralen Rationalität durch Nelson und Winter auch Foss 2003, 248ff.). Allerdings betonen Nelson und Winter selbst in der Einführung zu ihrem Buch, dass ihr Ansatz in Relation zu anderen verhaltensbasierten Theorien über das Unternehmenshandeln (hierbei wird u.a. auf die SCP Bezug genommen) relativ einfach und stilisiert sei (s. Nelson/Winter 1982, 6). Ihr Modell ziele eher auf die Mesoebene im Sinne der Betrachtung des Verhaltens einer Firmenpopulation (s. ebd.). Zumindest die Fokussierung auf die Routine und die Subsumierung der Innovation unter den Routinebegriff werden jedoch auch in den aktuelleren Publikationen der beiden Autoren, die sich mehr mit der Unternehmensebene beschäftigen, aufrechterhalten. Dies zeigt sich insbesondere in den Publikationen von Winter in Verbindung mit dem der Organisations-

[30] Die Autoren beziehen sich hierzu auf den ‚späten' Schumpeter, was aus Sicht der Autorin nicht gerechtfertigt ist (s. Fn 5).

[31] Siehe weiterführend zu einer kritischen Diskussion auch Felin/Foss (2011) in einer Sonderausgabe des ‚Journal of Institutional Economics' sowie die Antwort von Winter (2011) in derselben Ausgabe.

bzw. Managementforschung zuzurechnenden Konzept der ‚Dynamic Capabilities' (s. z.B. Helfat/Winter 2011; Jacobides/Winter 2012; Winter 2000; s. aber z.B. auch Nelson 2009).[32]

Dosi setzt sich (auch in unterschiedlichen Co-Autorenschaften) aus verschiedenen Perspektiven mit dem Konzept der beschränkten Rationalität auseinander und betont dabei die Relevanz der SCP für die evolutionsökonomische Theorieentwicklung (s. Dosi 2004). So entwickelt Dosi u.a. in Analogie zum Konzept der beschränkten und der prozeduralen Rationalität das Konzept der substantiven und prozeduralen Unsicherheit, welche das Entscheidungsverhalten von Unternehmensakteuren determiniert (s. Dosi/Egidi 1991, 146). Der Begriff der substantiven Unsicherheit bezieht sich dabei darauf, dass Akteuren nicht alle relevanten Informationen über das Umfeld zur Verfügung stehen, der Begriff der prozeduralen Unsicherheit charakterisiert die eingeschränkte Befähigung von Akteuren, Entscheidungen zu treffen und Probleme zu lösen. Hierbei werden auch die Relevanz von Lernprozessen und die Differenzierung zwischen bzw. die Interdependenz von Routine und Problemlösungsprozessen thematisiert (s. z.B. Dosi/Egidi 1991; Dosi et al. 1996; Dosi et al. 2011; Marengo et al. 2000). Zur Konkretisierung des Handlungsraumes von Problemlösungsprozessen wird sich dabei auch auf experimentelle Befunde bezogen (s. Dosi/Egidi 1991, 149f.), etwa die von Tversky und Kahneman identifizierten Framingeffekte (s. Tversky/Kahneman 1981). Dosi und Egidi (1991, 165) betonen dabei, dass das marktliche Innovationshandeln durch Problemlösungsprozesse eines spezifischen Akteurstyps bestimmt wird, „innovative player" (ebd., 157) genannt, und dabei abhängig ist vom jeweiligen Wissens- und Informationsstand. Im Problemlösungsprozess werden bestehende Routinen zur Problemlösung genutzt und neue Routinen geschaffen. Die Diffusion von Innovationen stellt sich dann über die Diffusion der neuen Routinen her. Die beständig vorherrschende Differenz zwischen bestehenden und neuen Routinen wird dann als das schumpeterianische Innovationsverhalten bezeichnet.

[32] Der ‚Dynamic Capability'-Ansatz ist ein relativ junges Forschungsfeld der Organisationsforschung, dessen Augenmerk auf die Befähigung von Unternehmen gerichtet ist, in unsicheren und dynamischen Umwelten zu agieren. Angenommen wird, dass hierzu eine Adaption und Weiterentwicklung interner Prozesse und Fähigkeiten notwendig ist (s. grundlegend Eisenhardt/Martin 2000; Teece/Pisano/Shuen 1997). Derzeit ist der Ansatz von zwei Richtungen bestimmt: Zum einen von den Autoren, die sich mit Teece, Pisano und Shuen (1997) und Teece (2007) relativ stark am Innovationskonzept der SCP orientieren, und zum anderen von den Autoren, die sich nach Eisenhardt und Martin (2000) sowie auch Winter (2003) relativ eng am Routineverständnis von Nelson und Winter (1982) orientieren und ‚Dynamic Capabilities' entsprechend als Routinen verstehen.

Deutlich wird, dass auch Dosi sich relativ stark auf den Routinebegriff fokussiert. Entsprechendes findet sich bei ihm in jüngerer Zeit ebenfalls im Rahmen des Konzeptes der ‚Dynamic Capabilities' (s. z.B. Dosi et al. 2008; Dosi/Nelson 2010). Insgesamt ist zu konstatieren, dass Dosi zwar wesentliche Aspekte der SCP aufnimmt, eine Vertiefung jedoch nur partiell erfolgt. Die Konkretisierung der beschränkten Rationalität etwa erfolgt unter Bezugnahme auf die oben angesprochenen Forschungen von Tversky und Kahneman (s. Dosi/Egidi 1991, 149f.) und nicht auf die SCP.

Einen umfassenderen akteursbasierten Ansatz verfolgt auch *Witt*, z.B. in seinem Werk ‚Individualistische Grundlagen der Evolutorischen Ökonomik' (Witt 1987; s. hierzu und zu Folgendem auch Daskalakis 2002, 39ff.; s. Buenstorf 2012, 5). Der Autor formuliert unter Bezugnahme auf das Konzept der beschränkten Rationalität der SCP sowie auf die Psychologie, die Soziologie und die Genetik ein Modell des Neuerungshandelns, welches Beschränkungen (u.a. die Gedächtniskapazität), Potentiale (u.a. die Lernfähigkeit), relevante Motivationsarten (u.a. die Leistungsmotivation), Persönlichkeitsfaktoren (u.a. Kreativität und Risikobereitschaft) sowie das Satisfizierungshandeln umfasst. Umfeldfaktoren wie Erziehung und Kultur beeinflussen bzw. bedingen Motivation und Zielsetzung in wechselseitiger Interdependenz. Diese relativ breite Perspektive auf den Akteur hält Witt auch in seinen aktuellen Publikationen aufrecht, wobei sich der Fokus stärker auf die Frage der evolutionsbiologischen Grundlagen als Determinanten von Handlungen ausrichtet (s. z.B. Witt 2011).

Bei der Betrachtung des Innovationshandelns von Unternehmen konkretisiert sich Witts Ansatz in der Analyse des Akteurstypus ‚Unternehmer'. Unternehmerpersönlichkeiten im Sinne von Schumpeter sind dabei die zentralen Träger des Unternehmenshandelns im Allgemeinen und des Innovationshandelns im Besonderen (s. hierzu grundlegend Witt 1998; 2000; 2001). Sie geben dem Unternehmenshandeln Ziel und Richtung vor, sofern es ihnen gelingt, die entsprechenden Vorhaben in ein (kognitives) Konzept zu übertragen, welches von den einzelnen Mitgliedern des Unternehmens akzeptiert und verfolgt wird.[33] Witt subsumiert dies unter dem Begriff der „cognitive leadership" (Witt 1998, 15). Das Gelingen dieser „cognitive leadership" hängt ab von individuellen Eigenschaften des Unternehmers wie Kommunikations-

[33] Die Bereitschaft, sich in der Gruppe anzupassen, wird von Witt und Schwesinger (2012) in Bezug auf das Verhalten von Akteuren in Unternehmen weiterführend aus einer evolutionsgenetischen Perspektive diskutiert.

fähigkeit, Fairness und Überzeugungskraft. Witt grenzt seinen Ansatz explizit von dem Unternehmenskonzept von Nelson und Winter ab, insbesondere auch von deren Fokussierung auf die Routine (s. hierzu und zu Folgendem Witt 2001, 3ff.; s. auch Witt 2011, 161 mit Blick auf die Relevanz einer individualistischen Perspektive auf die Routine). Unternehmerisches Handeln ist demnach gerade dadurch gekennzeichnet, dass es nicht routinisiert ist, Innovationen fokussiert und auf individuelle Persönlichkeiten und Persönlichkeitsmerkmale zurückzuführen ist (s. Witt 2001, 6, Fn 4). Ein relevanter Gegenstandsbereich des unternehmerischen Handelns ist zudem die Fähigkeit, neues (wissenschaftliches) Wissen aufzunehmen, die hieraus resultierenden marktlichen Potentiale wahrzunehmen und diese im Unternehmen umzusetzen (s. grundlegend Witt/Zellner 2005; 2009). Inwieweit dies möglich ist, hängt neben den individuellen Merkmalen des Unternehmers auch von der spezifischen Ressourcenausstattung des Unternehmens ab – und kennzeichnet dann die innovative Performance des Unternehmens (s. ebd; ebd.). Witts Perspektive ähnelt somit im Kern der SCP, ist aber pointierter auf den Unternehmer gerichtet. Dabei könnte die Wahrnehmung von Potentialen der Initiation zugerechnet werden, die Umsetzung dann entsprechend der Innovation. Allerdings ist festzustellen, dass auch Witt diese Aspekte der SCP nicht referiert.

Die kurze Darstellung der drei Ansätze relevanter Protagonisten einer akteursbasierten Perspektive im Rahmen der Evolutionsökonomik gibt bereits Hinweise darauf, dass in der Evolutionsökonomik zwar Bezug auf die SCP genommen wird, die Bezugnahme jedoch nur begrenzt über das Konzept der beschränkten Rationalität hinausgeht. Insbesondere wird weder das auf Individuen noch das auf Unternehmen bezogene Innovationskonzept (einschließlich des Initiationskonzeptes) systematisch betrachtet. Damit fehlt auch eine entsprechende Fundierung eines Akteurskonzeptes. Dies soll im Folgenden auch anhand der Ergebnisse einer kurzen *bibliometrischen Analyse* illustriert werden.

Im Rahmen dieser Analyse wurden 5.064 in Fachzeitschriften publizierte Artikel identifiziert, welche der Evolutionsökonomik zugeordnet werden können (s. zur Vorgehensweise Anhang 7.1). Nur in 6,3 % von diesen finden sich im Volltext Begriffe, die sich auf das Konzept der beschränkten Rationalität beziehen, und in 3,9 % werden Simon oder die Carnegie-School wörtlich genannt. Diese Anteilswerte verändern sich etwas, wenn, im Sinne der vorliegenden Fragestellung, nur diejenigen Artikel betrachtet werden, die sich im Volltext explizit auf die Innovation beziehen, dies sind 1.834 Artikel (36,2 % der Gesamtzahl von 5.064). 13,0 %, d.h.

239 dieser Artikel, beziehen sich auf die beschränkte Rationalität und in 8,4 % der Artikel werden wörtlich Simon und/oder die Carnegie-School genannt. Weitere Auswertungen zeigen dann, dass die Trefferquote sehr deutlich absinkt, je mehr spezifische Begriffe der SCP in den Suchalgorithmus aufgenommen bzw. verwendet werden. Zum Beispiel finden sich die Themenbereiche beschränkte bzw. prozedurale Rationalität, Anspruchsniveau und Problemlösen gemeinsam nur noch in 0,12 % [sic!] der Artikel, die sich auf das Innovationsgeschehen beziehen.

Eine manuelle Sichtung der Abstracts sowie, partiell, der Volltexte der oben genannten 239 Artikel zeigt, dass sich keiner der Artikel mit dem Innovationskonzept der SCP und entsprechend auch keiner mit dem Initiationskonzept befasst. Vielmehr werden jeweils eher Einzelaspekte des Akteurshandelns ohne weitere Bezugnahme auf die SCP betrachtet, z.B. Routinen, Dynamic Capabilities, Wissen, Lernen und soziale Netzwerke.[34] Methodisch sind die Artikel überwiegend auf theoretische Diskussionen ausgerichtet, 11 Artikel (4,6 %) beinhalten Simulationsmodelle, welche im Kern als Multi-Agentensysteme bezeichnet werden können, und lediglich 4 Artikel (1,6 %) basieren auf einer genuinen Erhebung von Daten.

Nun sind die Ergebnisse derartiger bibliometrischer Analysen immer mit Vorsicht zu interpretieren, nicht zuletzt weil sie einerseits stark vom jeweiligen Zugang der Suchmaschinen zu Artikeln bzw. von den durch die jeweiligen Universitätsbibliotheken bereitgestellten Zugangsberechtigungen zum Abfragedatum abhängen, und weil andererseits publizierte Artikel nur einen Ausschnitt der Forschungsleistung eines Forschungsfeldes repräsentieren. Trotzdem lässt sich aus den doch relativ eindeutigen Ergebnissen der vorliegenden Analyse darauf schließen, dass, wie oben angemerkt, die Anzahl der Artikel, die Bezug auf die SCP nehmen, in Relation zu der Anzahl der Artikel, die der Evolutionsökonomik zuzurechnen sind, sehr gering ist. Dies zeigt sich umso mehr, je mehr Begrifflichkeiten des Konzeptes der prozeduralen Rationalität im Innovationszusammenhang von der Suchabfrage erfasst werden.

Entsprechende Befunde werden von weiteren, allerdings nicht ausschließlich auf die Evolutionsökonomik bezogenen Untersuchungen bestätigt. So stellen Gavetti et al. (2007) zwar fest,

[34] Wenige der Autoren sind dabei grundsätzlich damit befasst, ein Gesamtkonzept zum Akteurshandeln im Allgemeinen zu entwickeln (s. aber mit jeweils unterschiedlichen Ansätzen Day 2008; Fernández-Huerga 2008; Herrmann-Pillath 2009; Vromen 2006; Witt 2008b).

dass im Zeitraum 1955 bis 2006 nahezu 10.000 Zitationen eines der drei Hauptwerke der Carnegie-School in wissenschaftlichen Zeitschriften zu zählen sind, jedoch auch, dass eine konkrete inhaltliche Auseinandersetzung kaum erfolgt. Ähnlich verweist Foss in Bezug auf die Verwendung des Begriffes ‚bounded rationality' darauf, dass dessen Sachverhalt eher selten konkretisiert wird und der Begriff zumeist lediglich als Hintergrundannahme fungiert. Foss spricht hier sogar von einer „rhetorical function" (Foss 2003, 245; s. auch Augier/March 2003, 4; Dosi 2004, 215; Gigerenzer/Selten 2001, 4; Witt 1987, 103).

Des Weiteren kann noch festgestellt werden, dass die oben aufgeführte niedrige Ausprägung originärer akteursorientierter empirischer Untersuchungen mit den Ergebnissen der bibliometrischen Analyse von Silva und Teixeira (2009) übereinstimmt, welche feststellen, dass von den von ihnen untersuchten 1.579 Publikationen mit Bezug zur Evolutionsökonomik, die nicht der evolutionären Spieltheorie zuzuordnen sind, lediglich 2,3 % auf einer originären Erhebung beruhen.

Woran kann nun die relativ geringe Bezugnahme auf eine Akteursbasierung oder auf die SCP im Allgemeinen bzw. das Innovationskonzept der SCP im Besonderen und mit Blick auf die Methodik die niedrige Anzahl empirisch orientierter Artikel liegen?

- Hinsichtlich der Rezeption des Innovationskonzeptes der SCP durch die Evolutionsökonomik könnte eine Ursache im Konzept von Nelson und Winter (1982) bzw. in deren zentraler Bezugnahme auf die Routinen als zentralem Handlungsmodus liegen. Dies hat möglicherweise dazu geführt, dass hierdurch inspirierte nachfolgende Forschungen ebenfalls eher auf Routinen fokussieren bzw. das Innovationskonzept nicht wahrnehmen (s. hierzu, allerdings ohne spezifischen Bezug zum Innovationskonzept, ausführlicher Foss 2003, 256ff.; s. auch Gavetti et al. 2007, 524).
- Eine weiterer potentieller Grund der relativ geringen allgemeinen Rezeption der SCP deutet sich schon im Rahmen der in den Abschnitten 2.1.1 und 2.2.1 referierten Ausführungen von Veblen und Nelson an und zeigt sich insbesondere am Beispiel Simons, der Psychologie und Ökonomik verband (s. Abschnitt 2.1.2.1): Die Ökonomik ist bislang darauf angewiesen, sich in Bezug auf empirisch fundierte Erkenntnisse über das Entscheiden und Handeln von Akteuren auf die Psychologie als genuin hiermit befass-

ter Fachwissenschaft zu beziehen und deren Erkenntnisse an den die Ökonomik betreffenden Handlungszusammenhang zu adaptieren (s. auch Simon 1997a, 70ff.).[35] Entsprechend ist das Werk Simons ausgerichtet und auch die drei Standardwerke der Carnegie-School beinhalten eine Auseinandersetzung mit psychologischen Konzepten bzw. eine Bezugnahme auf solche (zum damaligen Stand s. z.B. March/Simon 1993, 28ff.; s. hierzu auch Gavetti et al. 2012, 6ff.). Damit stellt sich die Frage, ob sich diese Bezugnahmen für Ökonomen ohne entsprechende Kenntnisse der relevanten fachwissenschaftlichen Konzepte und Terminologien hinreichend erschließen, und dabei insbesondere auch die Frage, inwieweit die eher kognitionswissenschaftlich ausgerichteten Schriften Simons überhaupt hinreichend zur Kenntnis genommen werden (können).[36, 37]

- Hiermit zusammenhängend kann weiterhin vermutet werden, dass die fehlende empirische Validierung aus einem methodischen Problem resultiert, welches in Abschnitt 2.2.1 bereits angesprochen wurde. So verweist Simon selbst darauf, dass eine Mikrofundierung in seinem Sinne nicht mit den traditionellen Methoden und aggregierten Daten der Ökonometrie zu erfassen ist (s. grundlegend Simon 1995a; s. auch Simon 1984, 40; 1986b, 4ff.). Notwendig sei vielmehr die originäre empirische Erhebung realer Mikrodaten und die Verwendung von Methoden, die es besser ermöglichen, komplexere (kausale) Sachverhalte zu erfassen als etwa Regressionsanalysen; Simon verweist hier auf die Methode der Strukturgleichungsmodellierung (s. Simon 1995b, 121; 2001, 46; s. auch Abschnitte 3 und 4.3). Ein Blick auf die auch von der Psychologie

[35] An der Relevanz der Bezugnahme auf die Psychologie ändern auch – zumindest zum derzeitigen Stand – die Forschungen im Bereich der experimentellen Verhaltensökonomik bzw. genauso der Neuroökonomik nichts, denn diese sind zumeist mit der Analyse von Anomalien in Bezug auf die dem traditionellen ökonomischen Akteurskonzept zu Grunde liegenden Eigenschaften befasst und weniger mit der Erstellung eines positiven, in der Realität verankerten Akteurskonzeptes (s. auch Berg/Gigerenzer 2010; Güth 2008; Rubinstein 2006; Simon 1995a; Herrmann-Pillath 2009; Witt 2013). In diesem Sinne beschäftigen sie sich auch weniger mit den Grundlagen des Innovationshandelns (s. aber zu Einzelaspekten des Innovationsverhaltens Cantner et al. 2009; Gächter et al. 2010; Güth et al. 2012; Morone et al. 2007; Schweizer 2006).

[36] Eine Bezugnahme auf die Psychologie setzt insofern einen relativ hohen Forschungsaufwand voraus, welcher nur bedingt mit der derzeitigen Publikationskultur in den Wirtschaftswissenschaften vereinbar ist (zumal nicht sicher ist, ob derartige, nicht am Mainstream ausgerichtete Forschungen in den relevanten Journals überhaupt zur Publikation angenommen werden).

[37] Hieraus lässt sich vielleicht auch ein Befund von Foss (2003, 256ff.) erklären, welcher feststellt, dass die Ökonomen das Konzept der beschränkten Rationalität eher als Negativkonzept wahrnehmen, und ignorieren, dass Simons Ansatz ein Positivkonzept beinhaltet.

verwendeten Methoden der empirischen Sozialforschung zeigt dann erwartungsgemäß, dass deren direkt am Akteursverhalten ansetzende Umfragen i.d.R. eine komplexere Gestaltung der zu erhebenden Daten und der Auswertungsmethoden beinhalten und voraussetzen. Eine derartige Fassung empirischer Untersuchungen setzt insofern, neben der grundsätzlichen Frage der inhaltlichen Auseinandersetzung mit (zumindest derzeit) fachfremden Erkenntnissen und deren Adaption, auch eine Auseinandersetzung mit für die Ökonomik neuen Methoden voraus.

- Schließlich kann vermutet werden, dass die Zurückhaltung der Evolutionsökonomen in Bezug auf eine Akteursorientierung im Sinne der SCP mit den Schwierigkeiten zusammenhängt, die sich ergeben, wenn das Konzept der beschränkten Rationalität nicht nur als eine Kritik des standardökonomischen Ansatzes, sondern auch als Leitfaden für ein positives Konzept verstanden wird (s. auch Foss 2003, 256ff.). Denn dann stellt sich nicht nur die Frage, welche Beschränkungen und Aktionspotentiale zu berücksichtigen sind, sondern auch, wie sich diese zeitabhängig und zumal in Interdependenz mit dem Umfeld verändern (etwa vermittelt über individuelle und/oder kollektive Lernprozesse). Die Beantwortung dieser Frage führt zu einem konzeptionellen und methodischen Design, das nicht allein formal-analytisch an die Fragestellung herangeht. Vielmehr erscheint die Verwendung der Methode der Computersimulation, d.h. insbesondere von Multi-Agentensystemen (s. Abschnitte 3, 4.4 und 4.5) von Bedeutung. Dies setzt jedoch wieder die Einarbeitung in einen (derzeit) fachfremden Gegenstandsbereich voraus, denn die Entwicklung entsprechender Befähigungen zur Konzeptualisierung und zur Operationalisierung in Algorithmen oder gar diese umsetzende Programmierkenntnisse gehören nicht zum Standardrepertoire von Ökonomen.

2.3. Zusammenfassung und kritische Würdigung

Im Abschnitt 2.1 wurde zunächst der konzeptionelle Hintergrund der akteursbezogenen Orientierung der vorliegenden Arbeit aufgezeigt, beginnend mit einer kurzen Darstellung der Perspektiven von Veblen und Schumpeter. Gemeinsame Merkmale der beiden Ansätze sind die Abgrenzung vom traditionellen Akteurskonzept der Ökonomik, die alternative Beschreibung von Akteursmerkmalen und -eigenschaften, die für Innovationen von Bedeutung sind (etwa Durchsetzungskraft und Experimentierfreude), die Rolle, die den innovierenden Akteu-

ren im wirtschaftlichen Prozess zugewiesen wird, und, hiermit zusammenhängend, die evolutorisch geprägte Perspektive auf den Wirtschaftsprozess. Veblen thematisiert dabei stärker als Schumpeter die Bedeutung von Umfeldbedingungen, einschließlich der Relevanz von Kooperationen; Schumpeter hingegen beschäftigt sich deutlich umfassender mit dem Prozess der wirtschaftlichen Entwicklung selbst. Beide Ansätze beinhalten somit wesentliche Merkmale einer akteursbasierten Theorie der wirtschaftlichen Entwicklung als Alternative zum standardökonomischen Ansatz. Allerdings ist u.a. zu konstatieren, dass die Akteurskonzepte relativ rudimentär sind, die Herleitung der Akteurseigenschaften nicht explizit theoretisch fundiert wird und auch keine empirische Validierung erfolgt. Zudem ist Schumpeters Innovationskonzept nicht auf die Inventionen bezogen und ist damit für Evaluierung der Determinanten von Inventionen, d.h. auch von F&E-Aktivitäten in Unternehmen, weniger geeignet, während Veblen spiegelbildlich weniger die Innovation bzw. die Diffusion betrachtet.

Das Akteurskonzept der SCP, welches in Abschnitt 2.1.2 vorgestellt wurde, ist, entsprechend dem Forschungszuschnitt, deutlich umfassender als die Konzepte von Schumpeter und Veblen. Gemeinsam ist den drei Ansätzen dabei u.a. die Zuschreibung von innovationsspezifischen Akteurseigenschaften. Das Konzept der prozeduralen Rationalität bzw. insbesondere das hiermit verbundene Innovationskonzept der SCP erfasst jedoch wesentlich detaillierter spezifische akteursbasierte Aspekte und Prozesse. Insofern können die Konzepte von Veblen und Schumpeter als genuine Ansatzpunkte für die Entwicklung eines akteursbasierten Ansatzes angesehen werden, das Akteurskonzept der SCP jedoch bietet eine breitere und grundlegendere theoretische Basis für eine entsprechende innovations- bzw. evolutionsökonomische Perspektive. Anzumerken ist, dass die SCP entsprechend ihrer Forschungsausrichtung die marktlichen Prozesse, die aus den Innovationsentscheidungen und -handlungen von Akteuren resultieren, kaum thematisiert. Auch sind wiederum einige Aspekte kritisch aufzuführen. So fehlt unter anderem eine empirische Validierung des Konzeptes der Initiierung und der Durchführung von Innovationen auf der Unternehmensebene.[38] Und auch bei der Be-

[38] Eine Ausnahme hierbei ist zumindest im Ansatz bei Cyert und March zu finden, welche im Rahmen von vier Fallbeispielen Suchprozesse von Unternehmen erforschen, dies jedoch nicht explizit auf eine Innovation bezogen, auch wenn das Fallbeispiel Nummer vier, die Einführung eines Datenverarbeitungssystems, als Organisationsinnovation angesehen werden kann (s. Cyert/March 2001, ff.). Die Untersuchung von Cyert und March konzentriert sich dabei u.a. auf die Frage der Kosten der Informationsbeschaffung und die Konflikte zwischen den am Prozess teilhabenden Unternehmensmitgliedern und nicht so sehr auf die akteursbasierten Merkmale.

schäftigung mit dem individuellen Problemlösungshandeln wurden die entsprechenden Erkenntnisse innerhalb eines Forschungsdesigns gewonnen, welches sich auf die Untersuchung von spezifischen, nicht unmittelbar ökonomischen Gegenstandsbereichen bezog, wie etwa das Schachspielen und/oder die wissenschaftliche Erfindung (s. auch die entsprechenden einschränkenden Anmerkungen von Newell und Simon; s. Newell/Simon 1972, 847f.). Zudem ist festzustellen, dass einzelne Aspekte des Innovationskonzeptes, wie etwa die relevanten Akteurseigenschaften, nicht weiterführend theoretisch fundiert werden und ferner die Handlungsmotivation zumindest in Bezug auf das Innovationsverhalten von Individualakteuren nicht analysiert wird (in Bezug auf Unternehmensakteure kann angenommen werden, dass die Satisfizierung der Unternehmensziele die Motivation darstellt). Hier hätten die Erkenntnisse der Kreativitätsforschung bzw. der Gestaltpsychologie, mit welcher sich die drei Autoren gerade auch in Bezug auf die Analyse von Problemlösungsprozessen intensiver auseinandergesetzt haben (s. March/Simon 1993, 119; Newell et al. 1958, 164f.; Simon 1996, 163), stärker einbezogen werden können. Weiterhin nimmt die SCP zwar auf die Relevanz von Umfeldfaktoren Bezug, diese sind jedoch in Hinblick auf die Innovation kaum konkretisiert. Dabei wird auch nur begrenzt auf die Bedeutung von Innovationskooperationen (mit den Kooperationspartnern als Akteuren des Umfeldes) und die hiermit verbundenen spezifischen Prozesse sowie Akteursmerkmale, zum Beispiel Vertrauen, eingegangen.

Der Abschnitt 2.2 befasst sich dann mit zwei aktuellen Diskussionsfeldern, der Innovationsökonomik (in Abgrenzung zur Evolutionsökonomik im Sinne von Nelson (2012b), s. Abschnitt 2.2.1) und, schwerpunktmäßig, der Evolutionsökonomik. Hinsichtlich der Innovationsökonomik kann festgestellt werden, dass diese zwar grundlegende und insbesondere auch empirische Beiträge zum besseren Verständnis des Gegenstandsbereiches der Innovation bereitstellt, jedoch finden sich nur in Teilbereichen Beiträge zur Akteursfundierung bzw. zu einer theoretischen Fundierung im Sinne der Implementierung der innovationsbezogenen Befunde in den ökonomischen Theorierahmen. Dies begründet möglicherweise das von Cohen (2010) identifizierte Problem der Falsifikation der Ergebnisse der empirischen Innovationsforschung. Dabei ist auch festzustellen, dass die Standardindikatoren der empirischen Innovationsforschung mit – seit längerem bekannten – Problemen behaftet sind.

Die Evolutionsökonomik hingegen kann als eine Synthese und Weiterentwicklung der Konzepte von Veblen und Schumpeter angesehen werden, deren erklärtes Ziel die Formulierung

einer (realistischen) Alternative zur Neoklassik ist und in deren Mittelpunkt die Auseinandersetzung mit den Grundlagen des wirtschaftlichen Wandels steht. Die Ansätze der Evolutionsökonomik sind gleichwohl heterogen und nur ein Teil greift das Konzept der SCP auf. Die vorgenommene illustrierende bibliometrische Analyse verweist zudem darauf, dass diese Bezugnahme, wenn überhaupt, dann eher relativ allgemein vorgenommen wird. Zudem zeigt sich, dass nur ein geringer Prozentsatz der untersuchten Artikel auf einer originären empirischen Erhebung beruht. In diesem Sinne ist festzustellen, dass die Entwicklung eines akteursorientierten empirischen Untersuchungsdesigns der Evolutionsökonomik noch weitgehend aussteht (s. auch Dosi 2004, 213). Weiterhin zeigt sich auch, dass relativ wenige Autoren die von Nelson und Winter (1982) in Bezug auf den Gegenstandsbereich eingeführte Verwendung von Computersimulationen aufgreifen, um im Rahmen von Multi-Agentensystemen Mikro- und Meso- bzw. Makroperspektive zu verbinden.[39]

Zusammenfassend ist festzustellen, dass die Evolutionsökonomik eine wichtige Alternative zum neoklassischen Konzept darstellt, jedoch bedarf es einer vertiefenden Entwicklung eines Akteurskonzeptes und zur Fundierung der Analyse des ökonomischen Wandels noch vertiefender Forschungen sowie insgesamt einer methodischen Weiterentwicklung. Hier bietet es sich an, hinsichtlich der Akteurskonzeptionalisierung an der SCP anzusetzen (s. entsprechend auch Dosi 2004), denn diese erfasst Beschränkungen und Handlungspotentiale von Akteuren und beinhaltet eine explizite Auseinandersetzung mit den Grundlagen von Innovationsentscheidungen und -handlungen von Unternehmen. Angesichts der oben angeführten Defizite der SCP verspricht zudem eine Erweiterung, Vertiefung und möglicherweise auch eine Aktualisierung des Konzeptes durch Erkenntnisse der mit der Thematik befassten relevanten Nachbardisziplinen einen angemessenen Anwendungsrahmen für die Evolutionsökonomik. Eine Konkretisierung bzw. eine Adaption der SCP an empirisch zu prüfende Sachverhalte bietet ferner weiterführendes Potential im Hinblick auf die empirische Validierung eines Akteurskonzeptes, und die Verwendung von Multi-Agentensystemen verspricht ein besseres Verständnis der Grundlagen des wirtschaftlichen Wandels.

[39] Die fehlende empirische akteursbasierte Fundierung wirkt im Übrigen auch hierauf, denn zu einer hinreichend realistischen Kalibrierung sind empirische Erkenntnisse über das Entscheidungsverhalten und die Handlungen von Akteuren notwendig (s. zu einer entsprechenden Diskussion Chen 2013; Fagiolo et al. 2007; Marks 2007), an denen es entsprechend dem konstatierten Defizit im Bereich der akteursbasierten Empirie derzeit mangelt.

3. Einbettung und Gegenstandsbereiche der vorliegenden Artikel

Die vorliegende Arbeit beinhaltet fünf publizierte Artikel und versteht sich als Beitrag zu einer akteursbasierten Mikrofundierung des Innovationshandelns aus einer evolutionsökonomischen Perspektive, in deren Hintergrund der von Veblen und Schumpeter thematisierte Zusammenhang zwischen Innovationshandeln und wirtschaftlicher Entwicklung steht (s. Abschnitt 2.1.1) und die sich zur konkreten Ausgestaltung der Akteursspezfikationen auf die SCP bezieht (s. Abschnitt 2.1.2).[40] Insbesondere vier der Artikel (nachfolgend der erste, dritte, vierte und fünfte Artikel) setzen dabei vertiefend an ausgesuchten Untersuchungsgegenständen des Innovationsmodells der SCP an und erweitern bzw. spezifizieren dieses im Sinne der Ausführungen in Abschnitt 2.1.2. Der zweite Artikel hat dies auch zum Thema, widmet sich im Schwerpunkt aber der der Frage, wie verhaltensbasierte Aspekte im Rahmen von Umfragen zu erfassen sind; hieran setzt die empirische Untersuchung in Artikel 3 unmittelbar an. Vier der Artikel (Artikel 2, 3,4 und 5) entstanden in Zusammenhang mit zwei von der Volkswagenstiftung geförderten Forschungsprojekten.[41] Die nachfolgende Darstellung der Artikel sowie die entsprechende Reihung der Artikel in Abschnitt 4 erfolgt nicht nach chronologischen, sondern eher nach inhaltlichen Gesichtspunkten, indem der Betrachtungsrahmen sukzessive vom Individuum über das Unternehmen hin zu kooperativen und sektoralen Prozessen erweitert wird.

[40] Zur Wiedergabe der Artikel im Folgenden wurde entsprechend der Rahmenpromotionsordnung der Universität Kassel die Literaturverzeichnisse der einzelnen Artikel aufgelöst und in ein Literaturverzeichnis überführt, welches die gesamte Arbeit umfasst. Weiterhin wurden die Abbildungs- und Tabellennummerierung entsprechend auf die gesamte Arbeit bezogen. Nicht verändert wurden die journalspezifische Zitationsweise und die teilweise auch journalspezifische Verwendung des Britischem oder des Amerikanischem Englisch.

[41] Artikel 2, 3 und 4 entstanden in Zusammenhang mit dem Projekt „„2nd Order Innovations“? An Actor-oriented Analysis of the Genesis of Knowledge and Institutions in Regional Innovation Systems‘ (s. http://www.uni-kassel.de/beckenbach/index.php?option=com_content&view=article&id=22&Itemid=5&-lang=de; letzter Zugriff am 25.04.2013); Artikel 4 entstand in Zusammenhang mit dem Projekt ‚Ecological Perspectives of Modularisation – Exemplary Studies of an Innovation Pattern‘ (s. http://www.uni-kassel.de/beckenbach/index.php?option=com_content&view=article&id=14&Itemid=5&lang=de; letzter Zugriff am 25.04.2013. Beide Projekte befassten sich mit der Akteursfundierung von Innovationsprozessen, allerdings aus unterschiedlichen Perspektiven und mit verschiedener Schwerpunktsetzung.

Der *erste Artikel* (s. Abschnitt 4.1) hat den Titel ‚Invention and Innovation as creative Problem Solving Activities' (Beckenbach/Daskalakis 2012)[42] und beinhaltet eine Auseinandersetzung, Erweiterung und Vertiefung des Konzeptes des Problemlösungshandelns aus der den Individualakteur erfassenden Perspektive von Newell und Simon (1972) hinsichtlich des dort enthaltenen Erklärungspotentials von Innovationsprozessen (s. auch Abschnitt 2.1.2.1). Im Konzept von Simon und Newell stehen insbesondere wohldefinierte Problemlösungsprozesse prozedural rationaler Akteure im Vordergrund, deren Merkmal es ist, dass sowohl Problem als auch Ziel ex ante bekannt sind. Weiterhin wird angenommen, dass der Akteur über lösungsrelevante kognitive Heuristiken und Operatoren verfügt und eine mentale Repräsentation erstellt, welche Problemstellung, Ziel und Aktionspotentiale umfasst. Der Problemlösungsprozess wird dann als ein sequenzieller, rückgekoppelter Prozess beschrieben, in welchem sich Heuristiken, Operatoren und Ziele und damit auch die mentale Repräsentation verändern können.

Die Erweiterung des Konzeptes der SCP im Sinne der kritischen Würdigung in Abschnitt 2.3 erfolgt in diesem Artikel durch die Bezugnahme auf die Erkenntnisse der Kreativitätsforschung sowie der Kognitionswissenschaft. Dies beinhaltet insbesondere *erstens* eine Spezifizierung von schlecht definierten Problemlösungsprozessen, welche dadurch charakterisiert sind, dass sowohl Problemstellungen, Ziele und Prozesse nicht oder in unterschiedlichem Ausmaß bekannt bzw. vorhanden sind. *Zweitens* umfasst dies die für derartige Prozesse als relevant angesehenen Akteurseigenschaften, wie etwa die Ausprägung des (domänenspezifischen) Wissens, die kognitiven Fähigkeiten, die Motivation sowie Merkmale wie Neugierde, Risikobereitschaft und Entschlossenheit. Zudem wird *drittens* die Rolle von Umfeldbedingungen, einschließlich der dem Gegenstandsbereich zuzuordnenden Wissensdomaine, betrachtet. Hinsichtlich der Spezifikationen, die der Differenzierung von Invention (der Erfindung im Sinne von Schumpeter) und Innovation (der Umsetzung der Invention im Sinne von Schumpeter) zu Grunde liegen, wird sich dabei auf das ‚Geneplore'-Modell von Finke et al. (1992) bezogen. Dieses beschreibt kreative Problemlösungsprozesse als eine Rückkoppelung zwi-

[42] Die Idee zu diesem Artikel entstand in Zusammenhang mit Daskalakis (2002), der Artikel erweitert jedoch das dort behandelte Themenfeld erheblich. Der Artikel wurde erstmals als graue Literatur publiziert (Beckenbach/Daskalakis 2003). Weiterhin findet sich in dem Sammelband ‚Wissensökonomie und Innovation. Beiträge zur Ökonomie der Wissensgesellschaft' (Moldaschl/Stehr 2010) eine an die Thematik des Sammelbandes angepasste Version (Beckenbach/Daskalakis 2010).

schen generativen Prozessen, welche eine Problemfindung beinhalten, und explorativen Prozessen, in welchen dann die eher vagen Resultate des generativen Prozesses konkretisiert werden.

Der Artikel resultiert in einem Modell des Neuerungsverhaltens (verstanden als das Zusammenspiel von Inventions- und Innovationsprozessen), das den Problemlösungsprozess von der Erstellung der Invention bis zur Marktimplementation abbildet. Im Rahmen dieses Problemlösungsprozesses konkretisieren sich auf Basis der Ausprägung der relevanten Akteurseigenschaften Problemraum, Ziele, Heuristiken und Operatoren in einem rückgekoppelten, pfadabhängigen Prozess (a) der Generierung der Invention unter Bezugnahme auf die jeweilige Wissensdomaine, (b) der Spezifikation von Art und Ausprägung der Invention und (c) der Überleitung in den Umsetzungsprozess (d.h. die Innovation) durch die Rückkoppelung mit dem Umfeld sowie (d) der anschließenden Implantierung der Innovation im Wettbewerbsprozess. Deutlich wird insgesamt, dass verschiedene Phasen des Neuerungsprozesses differenziert werden können, in deren Rahmen nicht nur spezifische individuelle Faktoren für das Neuerungsverhalten von Bedeutung sind, sondern auch Umfeldeinflüsse in verschiedenen Formen.

Der *zweite Artikel* (s. Abschnitt 4.2) hat den Titel ‚Behavioural Foundations of Innovation Surveys' (Beckenbach/Daskalakis 2008). Er widmet sich einerseits vor dem Hintergrund des in den Abschnitten 2.2.1 und 2.2.2 identifizierten Defizits in Bezug auf die empirische Analyse des Innovationsgeschehens aus einer akteursorientierten Perspektive (s. auch Abschnitt 2.3) sowie andererseits der Kritik an der Standardindikatorik der Innovationsforschung (s. Abschnitt 2.2.1) der Frage, wie ein akteursbasiertes empirisches Forschungsdesign im Rahmen eines evolutionsökonomischen Theoriegerüstes zu operationalisieren wäre. Die Themenstellung des Artikels beinhaltet dabei zwar auch Aspekte der SCP (Abschnitt 2.1.2), nimmt aber *erstens,* im Sinne der in Abschnitt 2.3 diskutierten Relevanz der Einbeziehung von psychologischen Befunden als möglichem Ansatz, vorwiegend Bezug auf die ‚Theory of Planned Behavior' von Ajzen (1991) bzw. Fishbein/Ajzen (1975).[43] Diese untersucht die Determinanten einer

[43] Das ursprüngliche Konzept wurde von Fishbein/Ajzen (1975) als ‚Theory of Reasoned Action' bezeichnet; Ajzen erweiterte das Konzept und benannte es um in ‚Theory of Planned Behavior' (Ajzen 1991). Aktuell haben

Handlungsintention und geht zum einen davon aus, dass Intentionen in Handlungen resultieren, und zum anderen, dass die Kenntnisse über die Ausprägung dieser Determinanten die Prognose von Handlungen erleichtern. Der Ansatz ist nach Fishbein/Ajzen (2010, 24, 51) dabei als ein entscheidungstheoretischer Ansatz zu sehen: Die Verhaltensintention impliziert eine Entscheidung, eine bestimmte Handlung durchzuführen - oder auch nicht durchzuführen. Als relevante Determinanten der Handlungsintention werden drei Kernbereiche angeführt: die individuelle Einstellung zu einer Handlung, die wahrgenommenen sozialen Normen, d.h. die wahrgenommene Erwartung des Umfeldes in Bezug auf eine Handlungsausführung, und die wahrgenommene Kontrolle über die Durchführung der Handlung (etwa im Sinne der monetären Ressourcen). Diesen Determinanten liegen wiederum spezifische Vorstellungen (im Original ‚beliefs') der Akteure über die jeweiligen Sachverhalte zu Grunde. Die spezifischen Vorstellungen bestimmen dann jeweils die Ausprägungen der drei Determinanten und damit die Stärke der Handlungsintention. Die ‚Theory of Planned Behavior' beinhaltet somit Aspekte des Ansatzes der SCP, etwa mit Blick auf die Ressourcenausstattung und die Umwelteinflüsse[44] und bietet den Vorteil, dass sie bereits relativ umfassend empirisch fundiert ist (s. zu einer Übersicht aktuell Fishbein/Ajzen 2010; s. auch dort zu einem Vorschlag für ein Fragebogendesign; ebd., 453ff.). Im Rahmen des Artikels wird die ‚Theory of Planned Behavior' an den Sachverhalt der Innovation (im Sinne von Inventionen und deren Umsetzung) adaptiert. Dabei werden Anregungen für eine Operationalisierung der Fragestellung im Rahmen von quantitativen Befragungen gegeben.

Die Themenstellung des Artikels nimmt *zweitens* vor dem Hintergrund der evolutionsökonomischen Fragestellung auf den prozessualen und zeitabhängigen Charakter von Innovationen Bezug. Hierzu wird die Differenzierung zwischen wohldefinierten und schlecht definierten Problemlösungsprozessen (s. Abschnitt 2.1.2), einschließlich der hierfür relevanten Akteursmerkmale entsprechend Beckenbach/Daskalakis (2012, s. Abschnitt 4.1) aufgegriffen und in ein Modell der Abfolge von Problemlösungssequenzen überführt, welches den Prozess von der Problemfokussierung über Entwicklung, Design und Analyse als Schritte des (schlecht

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die beiden Autoren ihren Ansatz überarbeitet und neuere Erkenntnisse einbezogen, in diesem Zusammenhang wurde die neue Bezeichnung ‚Reasoned Action Approach' eingeführt (Fishbein/Ajzen 2010).

[44] Dieses Themenfeld wird im hier vorgestellten Artikel nicht spezifiziert, aber in Beckenbach et al. (2007b) angesprochen.

definierten) Inventionsprozesses und anschließend die Prototypenentwicklung, Test, Implementation und Diffusion als Schritte des (wohldefinierten) Innovationsprozesses erfasst. Dies beinhaltet erste Vorschläge zur empirischen Erfassung von Sachverhalten, die Pfadabhängigkeiten, relevante kognitive Ressourcen bzw. den Umgang mit diesen abbilden. Zudem wird vorgeschlagen, die Dynamik des Prozesses über die Differenzierung der oben genannten Sequenzen im Zeitverlauf zu erfassen. Der Artikel mündet in ein integriertes Modell der diskutierten akteurs- und prozessbezogenen Elemente. Ausgangspunkt ist die Innovationsintention, d.h. letztendlich die Entscheidung für oder gegen eine Innovation auf Basis der ‚Theory of Planned Behavior'. Sofern dann die Entscheidung für eine Innovation fällt, kommt das oben formulierte Prozessmodell zum Tragen.

Der *dritte Artikel* (s. Abschnitt 4.3) mit dem Titel ‚Behavioural determinants of eco-innovation. A conceptual and empirical study' (Daskalakis 2013a)[45] leistet unmittelbar einen Beitrag zur empirischen Fundierung des Innovationsgeschehens aus einer akteursorientierten Perspektive im Sinne der in Abschnitt 2.3 diskutierten Aspekte und in einem weiteren Sinne von Beckenbach/Daskalakis (2008; s. oben und Abschnitt 4.2). Der Schwerpunkt des Artikels liegt auf dem Initiationsmodell der SCP (s. Abschnitt 2.1.2.2), das in ein quantitatives Untersuchungsdesign und eine entsprechende Umfrage umgesetzt wird (entsprechend differiert Artikel 3 in seiner Schwerpunktsetzung von Artikel 2, welcher sich zur Akteursfundierung überwiegend auf die ‚Theory of Planned Behavior' bezieht). Hierzu werden Befunde der Kreativitätsforschung, der Psychologie sowie der Management- und Organisationsforschung aufgenommen. Weiterhin wird sich auf die Umweltinnovationsforschung (s. Abschnitt 2.2.1) bezogen, da der Untersuchungsgegenstand eine spezifische Umweltinnovation ist, die Bereitschaft nämlich (bzw. im Sinne von Fishbein/Ajzen (2010) die Intention; s. Abschnitt 4.2; s. auch oben) von deutschen Pkw-Zulieferern, Produktinnovationen im Sinne des §4 der End-of-Life Vehicles Directive (Directive 2000/53/EC)[46] der Europäischen Union bzw. des §8 in der nationalen Umsetzung (deutsche ‚Altfahrzeugverordnung'[47]) durchzuführen. Da die Umwel-

[45] Eine erste Version der Themenstellung findet sich in Daskalakis (2011b), der vorliegende Artikel ist sowohl inhaltlich als auch methodisch stark überarbeitet.

[46] Siehe http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32000L0053:EN:NOT; letzter Zugriff am 17.02.2013.

[47] Siehe http://bundesrecht.juris.de/bundesrecht/altautov/gesamt.pdf; letzter Zugriff am 17.02.2013.

tinnovationsforschung ein relativ junges Forschungsfeld ist, welches sich zumindest in der empirischen Ausrichtung relativ stark an der traditionellen Indikatorik orientiert (mit den entsprechenden Problemen, s. Abschnitt 2.2.1 und 2.3 sowie oben zu Artikel 2), wird mit dieser Themenstellung auch ein Beitrag zur Entwicklung der Umweltinnovationsforschung geleistet.

Als statistische Methode wurde im Sinne von Simon (s. Abschnitt 2.2.1; s. auch Abschnitt 2.3) die Methode der Strukturgleichungsmodellierung (SEM) ausgewählt. Diese kann als eine Verknüpfung von multiplen Regressions- und Faktorenanalysen angesehen werden, mittels derer (derzeit noch zumeist lineare) Zusammenhänge zwischen mehreren unabhängigen latenten Variablen und einer oder auch mehreren abhängigen latenten Variablen untersucht werden, wobei die latenten Variablen gleichermaßen sowohl abhängige als auch unabhängige Variablen darstellen können (s. zu einer Einführung Bollen/Pearl 2013; Hair et al. 2009; Kline 2011). Die SEM ermöglicht insofern die Untersuchung (relativ) komplexer kausaler Zusammenhänge, was als einer der wesentlichen Vorteile gegenüber statistischen Verfahren wie Probit-, Logit- oder OLS-Regressionen angesehen werden kann (s. grundlegend Wold 1980; Vinzi et al. 2010). Konkret wurde für die Auswertung im Rahmen des vorliegenden Artikels die Methode der ‚Partial Least Square'-Analyse gewählt, welche von dem Ökonometriker Wold als eine Alternative zu der in der Ökonometrie vorherrschenden Verwendung von Regressionsgleichungen entwickelt wurde. Sie hat u.a. den weiteren Vorteil, explizit keine Annahmen über die Art der Verteilung vorauszusetzen (s. Wold 1980, 47). Zudem wurden, den Empfehlungen der Richtlinie der ‚Statistical Task Force' der American Psychological Association (s. Wilkinson 1999; s. grundlegend Cohen 1988) sowie dem aktuellen Stand der SEM-Diskussion (s. Hair et al. 2012) folgend, die direkten und indirekten sowie die totalen Effektstärken betrachtet.

Die Wahl der Methode erlaubte es, das Initiationskonzept der SCP in ein relativ komplexes Hypothesengerüst zu überführen und die entsprechende Fragestellung im Rahmen des Fragebogendesigns für die empirische Untersuchung umzusetzen. Hierzu wurde das Modell der ‚Composed Eco-Innovation Structure' (CEIS) konzipiert. Es erfasst eine Wirkungskette von drei Größen: Von den allgemeinen umweltbezogenen Zielsetzungen als Oberzielen im Sinne der SCP über die regulationsspezifischen Zielsetzungen hinsichtlich der Umsetzung des §8

der Altfahrzeugverordnung als operationalisierten Zielen im Sinne der SCP bis zur entsprechenden Innovationsintention als finaler zu erklärender Variable.

Die dann in das Modell aufgenommenen Determinanten der CEIS, d.h. die jeweiligen Determinanten der drei latenten Variablen der Wirkungskette, können dahingehend unterschieden werden, ob sie sich im Allgemeinen auf innovationsbezogene Sachverhalte oder im Speziellen auf Umweltinnovationen beziehen. Untersucht wurde hierbei, in Adaption des Initiationsmodells, der Einfluss der Einstellung zur Innovation im Allgemeinen und zu Umweltinnovationen im Speziellen (im Sinne einer entsprechenden Akteurstypologisierung) sowie der Einfluss von innovationsrelevanten Akteursmerkmalen und Ressourcen und, als Ausdruck von Pfadabhängigkeiten, des vergangenen Umweltinnovationsverhaltens. Weitere Determinanten im Modell sind die ‚harten' ökonomischen Ziele, die antizipierte Wirkung von Marktbedingungen auf das Unternehmen und, in Bezug auf externe Einflüsse, die Wirkung der Krise in der Automobilindustrie. Im Ergebnis zeigt sich, dass das Modell relativ hohe Erklärungsgrade hat, insbesondere hinsichtlich der Umweltinnovationsintention, für welche der Determinationskoeffizient einen Wert von 0,42[48] aufweist.

Der *vierte* Artikel (s. Abschnitt 4.4) mit dem Titel „A procedural model of trust dynamics and knowledge exchange in collaborative R&D" (Daskalakis 2013b) befasst sich vertiefend mit den verhaltensökonomischen Grundlagen der Interaktion von Akteuren in F&E-Kooperationen.[49] Hierzu werden zwei Aspekte in Beziehung gesetzt, die zwar in der innovations- bzw. evolutionsökonomisch geprägten Literatur häufiger diskutiert werden, jedoch eher selten zusammengeführt werden: das dynamische Zusammenspiel von Wissensaustausch und Vertrauen bzw. der mit dem Vertrauen verbundenen Verhaltensaspekte.

Der Aufsatz ist als ein eher konzeptioneller Beitrag zu verstehen, der relevante Verhaltensmerkmale erfasst und in Beziehung setzt, um deren Wirkung und Wechselwirkung vor dem Hintergrund der Heterogenität von Akteuren zu untersuchen. Der Artikel behandelt dies auf drei Ebenen: *Erstens* erfolgt eine Konzeption eines Verhaltensmodells, *zweitens* wird dieses

[48] Zur Berechnung wurde entsprechend Leach/Henson (2007, 8) die Formel von Lord (1) (s. ebd., 3) verwendet, welche auf die Replizierbarkeit von Ergebnissen ausgerichtet ist.

[49] Die Grundidee zu diesem Artikel und das Differenzengleichungsmodell basieren auf Daskalakis/Kauffeld-Monz (2007), wobei hier die Beiträge der Autorin zu der Publikation inhaltlich wieder aufgenommen und erheblich modifiziert und erweitert wurden.

als Differenzengleichungssystem formalisiert und *drittens* werden die Gleichungen in eine Computersimulation, ein Multi-Agentensystem überführt.[50]

Der Artikel nimmt somit methodisch auf Nelson/Winter (1982) Bezug (s. Abschnitte 2.2.2 und 2.3). Dies ist mit den spezifischen Vorteilen von Multi-Agentensysteme zu begründen. Diese erlauben im Allgemeinen, die möglichen Pfade wirtschaftlicher Entwicklung aus einer akteursbasierten Perspektive zu untersuchen (s. zu einer Einführung zu dieser Methode z.B. Dawid 2004; Fagiolo et al. 2007; Heath et al. 2009; Railsback/Grimm 2012). Im Speziellen ermöglichen es Multi-Agentensysteme dabei, die Heterogenität von (prozedural rationalen) Akteuren zu erfassen, indem z.B. Akteurstypen, Lern- und Entscheidungsprozesse sowie Handlungsmodi definiert werden. Durch die Verknüpfung von individuellen Handlungen und Interaktion können dann Prozesse der marktlichen Selbstorganisation (s. hierzu Weise 2003; 2006) bzw. emergente Phänomene, die aus derartigen Prozessen resultieren, simuliert und analysiert werden. Üblicherweise werden mit Multi-Agentensystemen insofern eher die Wirkung des Akteurshandelns auf die Meso- und/oder die Makroebene untersucht (s. zu einer solchen Anwendung Beckenbach et al. (2012), Abschnitt 4.5).

Der vorliegende Aufsatz ist jedoch deutlich enger fokussiert. Hier wird die Methode der Computersimulation genutzt, um im Rahmen eines relativ schlanken Modells die Prozesse und Ergebnisse von Kooperationen unterschiedlicher Akteurstypen bzw. von systematisch unterschiedlich initialisierten Variablen und kalibrierten Parametern tiefergehend zu analysieren. Auf diese Weise kann die Zusammenwirkung mehrerer Verhaltensaspekte besser untersucht werden, als es mit einem umfassenderen Modell möglich ist.

Mit Blick auf die theoretische Basis wird sich auch in diesem Artikel auf die SCP bezogen und die prozedurale Rationalität als Verhaltenskonzept zu Grunde gelegt. Es wird dabei davon ausgegangen, dass kollektive Problemlösungsprozesse als Innovationsprozesse zu verstehen sind und diese gegenüber individuellen Problemlösungsprozessen einen Vorteil aufweisen können, welcher mit dem schrittweisen Charakter von Problemlösungsprozessen und der Heterogenität von Akteuren zu begründen ist. Beispielsweise können einzelne Problembe-

[50] Als Programmierumgebung wurde Mathematica® gewählt.

reiche des Prozesses auf jeweilig entsprechend qualifizierte Interaktionspartner verteilt und nach deren Lösung wieder in den kollektiven Problemlösungsprozess zurückgespielt werden.

Zu fragen ist dann, welche spezifischen Verhaltensaspekte in derartigen kooperativen Prozessen wirken. In den Abschnitten 2.1.2.1 und 2.3 wurde festgestellt, dass die SCP hierauf keine direkte Antwort hat. Gleichwohl ist mit dem Konzept der sozialen Einfügungsbereitschaft von Herbert Simon, welches ebenfalls im Abschnitt 2.1.2.1 kurz vorgestellt wurde, ein Ansatzpunkt zur Einbettung von interaktionsrelevanten Verhaltenskomponenten in das Konzept der prozeduralen Rationalität gegeben. Im Artikel wird hierauf aufbauend auf die Erkenntnisse der Vertrauensforschung Bezug genommen, da diese derartige Interaktionszusammenhänge thematisiert. Dies zusammenführend und auf den Gegenstandsbereich F&E-Kooperationen bezogen, werden im Rahmen des Artikels sieben Propositionen entwickelt, die in ihrer Gesamtheit das konzeptionelle Modell, das Kd-Td Modell bilden – ‚Kd' steht für ‚knowledge dimension' und bezieht sich auf die wissensbezogenen Aspekte der prozeduralen Rationalität, ‚Td' für ‚trust dimension' entsprechend auf die vertrauensbezogenen Aspekte. Hierbei werden auch spezifische Aspekte von Forschungs- und Entwicklungskooperationen thematisiert, insbesondere deren (auf das einzelne Kooperationsprojekt bezogener) finiter Charakter und das hieraus resultierende ‚window of opportunity for defection', welches sich gegen Innovationsende öffnet.

Die sieben Propositionen bilden dann die Grundlage des Differenzengleichungssystems mit drei Gleichungen. Dieses beinhaltet drei Variablen: den Wissensbestand, den Vertrauensbestand sowie die Menge an Wissen, welches mit den Kooperationspartnern geteilt wird. Weiterhin haben zwei Parameter einen Wissensbezug (absorptive Kapazität und Vergessen) und fünf Parameter bilden die Vertrauensdimension ab (die grundlegende Vertrauensbereitschaft, die Bereitschaft zu reziprokem Verhalten, die Bereitschaft, nicht reziprokes Verhalten zu tolerieren, sowie mögliches vorsichtigeres Verhalten im Zeitraum des ‚window of opportunity for defection' gegen Ende der Innovation).

Um Heterogenität in Betracht zu ziehen, werden weiterhin drei Akteurstypen definiert: ein Default-Typ, genannt STANDARD, ein Typ TRUST mit einer höheren Ausprägung der wissens- und vertrauensbezogenen Merkmale als STANDARD sowie ein Typ OPPORTUNIST mit einer niedrigeren Ausprägung der wissens- und vertrauensbezogenen Merkmale als STANDARD.

Das Modell ist dabei aus Gründen der Übersichtlichkeit auf drei Akteure beschränkt. Diese tauschen im Rahmen einer Kooperation Wissen aus mit dem Ziel, eine Innovation zu erreichen: Letztere wird als eine feste Anzahl von Wissenseinheiten definiert. Eine Kooperation endet, sobald die Anzahl der notwendigen Wissenseinheiten erreicht ist bzw. wird nach 100 Zeitschritten abgebrochen, sofern dies nicht erfolgt. Das Ausmaß des Wissensaustausches in jedem Zeitschritt hängt von den oben genannten individuellen Zuständen, einschließlich der Reaktion auf die erhaltene Wissensmenge, ab.

Um die Simulationsläufe zu strukturieren, wurde *erstens* eine Systematik der Veränderung der Variablen- und Parameterwerte entwickelt, welche unterschiedliche Szenarien beinhaltet, sowie *zweitens* Erfolgsindikatoren identifiziert, die sich auf die Wissens- und die Vertrauensdimension beziehen und die die Anzahl der Zeitschritte bis zur Innovation berücksichtigen. Zur Beurteilung der Ergebnisse der Szenarien wurden zudem Mittelwerte und Standardabweichungen berechnet. Auf diese Weise kann sowohl der unterschiedlichen Wirkung von Variablen und Parametern, der Heterogenität der Akteursmerkmale als auch der Wirkung von unterschiedlichen Gruppenzusammensetzungen Rechnung getragen werden. Im Ergebnis zeigt sich u.a., dass die wissensbezogene Ebene eine notwendige, aber keine hinreichende Bedingung für den Erfolg ist, bessere Ergebnisse können erzielt werden, wenn Wissens- und Vertrauensaspekte gemeinsam wirken. Weiterhin wird deutlich, dass eine zu große Heterogenität zu ‚überhitzten' Reaktionen führen kann, sodass damit zwar im günstigen Fall deutlich schneller die notwendige Wissensmenge erreicht wird, jedoch viele Kooperationen scheitern. Eine moderate Heterogenität hingegen führt zwar zu einer erheblich längeren Dauer der Kooperation, allerdings weisen die Akteure dann auch deutlich höhere Wissens- und Vertrauensbestände auf, was für mögliche weitere Kooperationen von Vorteil sein könnte.

Im *fünften* Artikel mit dem Titel ‚Agent Based Modelling of Novelty Creating Behavior and Sectoral Growth Effects – Linking the Creative and the Destructive Side of Innovation' (Beckenbach et al. 2012; s. Abschnitt 4.5) wird schließlich, wiederum Nelson/Winter folgend und die Überlegung aus Abschnitt 2.3 aufnehmend, das Konzept der SCP im Rahmen der Kalibrierung eines Multi-Agentensystems (s. hierzu auch oben) in sachlicher und zeitlicher Erweiterung umgesetzt. Dieses Multi-Agentensystem bezieht sich, im Gegensatz zu dem oben vorgestellten, auch auf eine übergeordnete Ebene, d.h. die Mesoebene von Sektoren.

In diesem Sinne überführt der Artikel zunächst in einem ersten Schritt das Konzept der SCP in einen erweiterten sachlichen und zeitlichen Betrachtungsrahmen, welcher in einem zweiten Schritt dann in ein Multi-Agentensystem umgesetzt wird. Den konzeptionellen Überlegungen liegt dabei ein ‚Zwei-Ebenen-Modell' zu Grunde: Die *erste Ebene* ist die Mikroebene der Agenten und beinhaltet eine Spezifikation der Determinanten der Innovationsentscheidungen und Innovationshandlungen von Unternehmen auf Basis der SCP (s. Abschnitt 2.1.2), wobei von einer zeitabhängigen Auflösung eines veränderlichen Spannungsfeldes zwischen dem Beharren auf Routinen und dem Innovationshandeln ausgegangen wird. Das Initiationsmodell der SCP wird in diesem Zusammenhang nicht direkt thematisiert, jedoch werden relevante Aspekte wie der Zusammenhang zwischen Zielen, Satisfizierung, Innovationsentscheidung und vorhandenem Slack aufgenommen. Dabei wird differenziert zwischen den Innovationsarten ‚failure induced search' , hier im Sinne von Produktimitationen, und ‚sucess induced search', hier im Sinne von Produktentwicklung (im Artikel unter dem Begriff ‚Innovation' subsumiert). Heterogenität in der Akteurspopulation stellt sich dann über die unterschiedlichen Ausprägungen der Innovationsspezifika her. Hierzu werden, aufbauend auf empirischen Befunden der Autorin, welche in Beckenbach et al. (2009) referiert werden, drei Akteurstypen differenziert: (a) konservative, neuerungsaverse Unternehmen, (b) vorsichtige, eher Imitationen durchführende Unternehmen und (c) experimentierfreudige Unternehmen mit einer Neigung zu radikalen Innovationen. Zentrale Determinanten der Generierung von Innovationen sind dabei auch der vorhandene Wissensstock und die Generierung von neuem Wissen (bzw. die Entwertung von bestehendem Wissen). In diesem Zusammenhang werden, im Sinne der neueren Diskussionen der Innovationsökonomik (s. Abschnitt 2.1.1) und der Ausführungen in Abschnitt 2.3, Innovationskooperationen und deren Bestimmungsgrößen als eine zusätzliche Option des Zugangs zu neuem Wissen in das Modell aufgenommen. Die *zweite Ebene* des Modells bilden Diffusionsdynamiken innovativer Produkte und die hiermit verbundene Entwertung bereits bestehender Produkte im Sinne der ‚schöpferischen Zerstörung' nach Schumpeter (s. Abschnitt 2.1.1) ab.

Die derart gefasste Spezifikation der zwei Modellebenen wird formalisiert und in das Multi-Agentensystem überführt. Das vorliegende Modell beinhaltet 23 Unternehmen, differenziert nach den oben genannten drei Akteurstypen (konservativ, vorsichtig, experimentell), welche vier Sektoren angehören. Die Simulationsergebnisse verweisen darauf, dass mit dem Modell

nicht nur die Selektion unterschiedlicher Handlungsmodi (Routine, Produktentwicklung, Imitation, individuelles und kooperatives Innovationshandeln) erklärt werden kann, sondern auch bekannte ‚stylized facts' reproduziert werden können, z.B. mit Blick auf heterogene Entwicklungspfade in Bezug auf Wissen und Handlungsmodi sowie auf zyklische Phasen der Generierung von Inventionen und der Ausbreitung von Innovationen in Form von Imitationen.

4. Ansätze einer akteursbasierten Innovationserklärung

4.1. Invention and Innovation as Creative Problem Solving activities (Artikel 1)

4.1.1. Background: Microeconomics of Novelty Creation and Problem Solving

Obviously, invention and innovation can be hardly analyzed from the usual cost/benefit perspective of economics. These processes are conjectural by their very nature:

- Because ex ante results of the search endeavor cannot reasonably be anticipated (or even expected)
- Because there is no guarantee for the social acceptance of a possible result
- Because there is the risk that an accepted result cannot be used as a source of (additional) private yield (Nelson 1959a, b, 1982)

Due to these intricacies, invention and innovation have previously been either considered as coming „out of the blue“ (Kirzner 1979; Vromen 2001) or have been simply postulated as an outcome of mesopatterns in terms of paradigms, routines, and institutions (Dosi 1988; Lundvall 1992).

Notwithstanding these caveats and provisos, various attempts to conceptualize the novelty creating process from a microeconomic perspective have been made (Kline/Rosenberg 1986; Noteboom 2000; Witt 2009). The common denominator of these attempts is that these novelty creating processes have essential features which can be dealt with analytically: (a) there are boundary conditions or triggers making the occurrence of these processes highly probable; (b) these processes can be divided in different phases, each of which is characterized by specificities in terms of cognitive resources, uncertainty, and economic constraints; (c) time matters not only in terms of succession and path dependency but also in terms of feedback loops with different range; (d) multiple types of behavior are included in these processes (especially deliberation and intuition); and finally (e) their social embedding has to be taken into account (especially related to the issues of acceptability and appropriation).

The concept of problem solving was initially figured out in Gestalt psychology (e.g., Wertheimer 1922) and afterward imported and specified for economic contexts by Herbert Simon (e.g., Simon 1965). According to Simon, problem solving is a cognitive device which

allows bounded rational agents to make decisions in a complex environment. Simon especially proposes his approach as a more realistically conception of human (and organizational) behavior than the standard approach of economics, namely, the expected utility concept. Nevertheless, there is an ongoing controversy about the question if the former concept is suitable for analyzing novelty creating processes (including invention and innovation) in terms of the features (a-e) mentioned above. This might be partially due to the fact that the core of the problem solving concept was developed by supposing simple problems or rather abstract themes (e.g., the „Tower of Hanoi“ – problem and chess).

4.1.2. The Core Concept of Problem Solving and its Restrictions

The starting point of the problem solving procedure is the perception of a „problem.“ „A person is confronted with a *problem*, when he wants something and does not know immediately what series of actions he can perform to get it [....]. To have a problem implies (at least) that certain information is given to the problem solver: information about what is desired, under what conditions, by means of what tools and operations, starting with what initial information and with access to what resources“ (Newell/Simon 1972, 72; Cyert/March 1992, 121). Hence, the essential feature of a problem is a divergence between the given and the desired state of affairs. The conditions for eliminating this divergence are on one side the initial constraints of the agent (in terms of money, time, and knowledge) and on the other side the (virtual and real) transformation devices (in terms of heuristics and operators) for the given state of affairs. Yet, the applicability of these transformation devices is uncertain in that there is only a rough idea about the appropriateness of these devices.

„Problem solving“ is the process of finding out a sequence of states between the initial and the desired final state under the given constraints. This process is based on a „mental representation, a mental scheme for holding information in memory and operating on it“ (Simon 1999b, 674; Newell/Simon 1972). The elements of the mental representation are:

- An interpretation of the given situation A listing of the transformation devices (operators derived from heuristics) according to this interpretation
- A test and evaluation mechanism for the results of operator application.

Hence, selecting a cognitive activity under the constraint of available knowledge and the experience about the problem domain marks the starting point of the problem solving process.

The listing of the transformation procedures within the mental representation is not complete because not all the procedures contained in the knowledge stock are activated. This would easily lead to a combinatorial explosion of transformation possibilities which, due to cognitive constraints, would have to be dealt with on a trial and error base. Therefore, the problem solver applies only a part of the available search procedures (heuristics) to reduce the size of the problem space, i.e., the space which is defined by applying all available transformation possibilities to all possible states. These heuristics might be either explicit in that they are explicable and even programmable or they might be implicit in that a given situation includes cues about what to do for the experienced problem solver.

However, only under ideal conditions problem solving will be a linear sequence of representation, operation, and realization. Normally, it will be a feedback process between the steps „operation“ and „representation“ as well as within the „operation“ step. Furthermore, if several attempts to reach a given goal are not successful, the goal itself might be modified (in quantitative or qualitative terms).

This sketch of the seminal contribution of Simon and Newell to the analysis of the elements and process of problem solving shows that this is a pathbreaking alternative to the standard model of the deliberate decision process (a) in that it focuses an open-ended search behavior divided in the statement of the given situation, the figuring out of the problem space, and finally the solution of the problem and (b) in that it integrates the assumption of bounded rationality in terms of knowledge-dependent problem representation and in terms of limited capabilities of problem manipulation (by heuristics and operators). Due to these cognitive constraints, the process of problem solving might become sticky and pathdependent.

Nevertheless – at least in its original form – the concept has a rather narrow scope. *First*, it takes only the goal-related outcome into account which abstracts from basic abilities of the agents as well as from individual specificities. *Second*, according to the computer-oriented

context in which this concept of problem solving was developed, it was mainly confined to clear cut („well-defined“) problems. This means that the goals of the agent as well as the heuristics used for reaching this goal are specified in such a way that the results of the application of these heuristics can be unambiguously evaluated with respect to their goal-reaching capability. Furthermore, it is assumed that this capability is even measurable in terms of a larger or smaller distance to the goal. *Third*, it is assumed that the definition of the problem and the finding of the problem solving devices are two separable elements and that the problem solving devices are merely instrumental for the problem itself. Thus, only these solution advices are varied during the problem solving process. Taking these limitations into account, one might become skeptical about the essential difference between this problem solving approach and the decision approach in standard economics. Furthermore, this simplistic problem solving approach has been criticized due to its affinity to what computers can do (instead to what humans used to do; cf. Dreyfus and Dreyfus 1986).

4.1.3. Enhancing the Concept of Problem Solving: Ill-Defined Problems and „Creative Problem Solving“

4.1.3.1. Ill-Defined Problems and Creativity Research

Not all problems in the economic world are well defined in the sense of the standard approach of problem solving. Sometimes, even the understanding of the initial situation is not in such a way clear that it can be transformed into a mental representation. Consequently, it remains vague in which way such a situation can be influenced by any kind of operator and which goals are appropriate for it. However, even if the situation is well understood, it might be difficult to solve a problem because there are multiple incommensurable problem spaces and/or a lack of appropriate operators/heuristics making it intricate to find a sequence of reasonable operations. Finally, it is possible that the goal is not defined in a unanimous manner. These caveats are the background for admitting „ill-defined problems“ (Simon 1973) and thereby broadening the scope of the concept of problem solving.

The inconveniences arising with ill-defined problems – which do normally occur in an uncertain world – change the character of the problem solving process. *First*, it is not any longer „directed“ insofar it successively reduces the gap between initial and final (goal-reaching) state; rather, it might circle around or even be regressive by broadening the gap. This is due

to the lack of appropriate operators/heuristics and/or the goal ambiguity. *Second*, the instrumental role of problem solving devices does not hold anymore if the problems are ill defined. Under this condition, heuristics and operators as emanations of the stock of knowledge are themselves influencing the way the problem is posed at every time step. Problem solving then becomes an iterative and simultaneous exploration of problems and solutions.

Solving ill-defined problems makes great demands upon the actors involved. At the core of the individual ability to look for new situations and to deal with them is the human creativity. Referring to the research on human creativity therefore helps to understand how ill-defined problems can be solved. This research has a long tradition starting when the ability to create something new is no longer considered as a divine inspiration but rather an individual capacity of the human being. However, even in the professional treatment of creativity in psychology, it took some time before single hypothesis approaches (such as the psychodynamic, associationist, and Gestaltist treatment) to this human ability have been overcome in favor of a broad treatment including all resources and processes known in modern cognitive psychology (Guilford 1950; Weisberg 2006).

The modern creativity research defines creativity as „the ability to produce work that is both novel (i.e., original, unexpected) and appropriate (i.e., useful, adaptive concerning task constraints)“ (Amabile 1996; Sternberg/Lubart 1999). Hence, what is meant by creativity in the sense of modern creativity research are the individual creative traits and processes. Creativity research does not primarily deal with the wide range of tacit everyday creativity. Rather, creativity here implies that the individual creative output (product) is being assessed and accepted by the environment. Following this definition, three different – although interdependent – aspects of creativity are emphasized in the modern creativity research: the individual qualities, the process analysis, and the environment. All these aspects are relevant for solving ill-defined problems and thereby broadening the scope of the original concept of problem solving (Weisberg 2006).

- The *individual qualities* can be subdivided in knowledge and skill endowment, motivation, and personality features. For being creative, knowledge is required about the domain specificities (Weisberg 1999). This knowledge should be well organized giving the possibility for switching flexibly between different levels of generalization.

Whereas this kind of knowledge is „declarative," also „procedural" knowledge is required in terms of knowing how to use available heuristics. These different levels of knowledge are accomplished by skills in terms of finding new heuristics and capabilities for recombination and association of given elements of knowledge (Chand/Runco 1993; Policastro/Gardner 1999). However, knowledge and skills are not sufficient for being creative: Additionally, a strong motivation for fulfilling a task is required. This strong motivation can either come from inside in that an individual views such an engagement as an end in itself (intrinsic motivation) or in that this motivation comes from outside following from external information or expectations without restricting the autonomy of the person under consideration (informational or enabling extrinsic motivation; Amabile 1996). Finally, some personal qualities are required for a creative activity. Among the most important ones are curiosity, the steadfastness of purpose, patience, and a fundamental willingness to bear risks (Csikszentmihalyi 2001). Knowledge, skills, motivation, and personality are combined in two overarching features of creativity: *deliberate cognitive style* and *divergent thinking*. A deliberate cognitive style is a stable preference for using extensively deliberate (conscious) resources in sorting out the possibilities of action (Kirton 1989). Divergent thinking is a specific way to use these cognitive resources. Convergent thinking has only one direction; one conventionally correct answer is searched for. Contrary to that, divergent thinking proceeds in different directions (Guilford 1959). Hence, the approach of creative individuals to problems is original in that they are breaking with traditional formulation and solution of problems, and it is flexible in that many ideas about formulation and solution are held for a long time simultaneously in mind until a switch to one of these options occurs (Amabile 1996).

- The *process analysis* of creativity was initially heavily influenced by the idea that the creation of something new is a rather unexplainable operation in terms of rational process analysis. This gap in explanation was either filled by referring to mysterious abilities of the human genius or it was assumed that creative ideas emerge from a largely uncontrollable Darwinian process of random variation and natural selection. This gap is well documented in one of the first process models of creativity by Wallas (1946). In this model, four phases are distinguished: (a) the definition of the issue and

the observation of the starting conditions in the phase of preparation, (b) then the phase of incubation in which the issue is laid aside, (c) the phase of illumination in which the new idea is born by picking up the issue after a while, and finally (d) the phase of verification. How this illumination can happen remained unexplained at that time. Furthermore, it seems dubious to separate this act of illumination from all conscious endeavors to analyze the issue. This lack of explanation was reflected in the process model of Rossman (1964). In this model, the preparation phase is composed of observation of need, analysis of need, a survey of all available information, and a formulation of all possible solutions. The incubation/illumination phases are replaced with a critical analysis of these possible solutions and a birth of the new idea out of this analysis. The last phase is analogous to Wallas (here based mainly on experimentation). How this „birth" of the new idea happens still remains mysterious. Meanwhile, these traditional conceptions have been challenged by at least two relevant approaches: On the one hand, the incubation/illumination paradox is explained as a cognitive process, relying on cognitive operations and not on mystical insights. Thereby, the features of the four-stage model are either updated (Amabile 1996; Cszikszentmihalyi 1999b) or rejected (Weisberg 1993). On the other hand, very promising endeavors have been made to propose new models to overcome the traditional perspective (Finke et al. 1992). Additionally, a lot of empirical and experimental work has been done to explain problem solving (and problem finding) processes (Runco/Sakamoto 1999; Lubart 2001).

- Creative operations do not happen in an empty space; they have an *environment*. This environment is relevant for the generation of a creative act as well as for the evaluation of the result of this creative act. According to the difference between the outcome of creativity (an idea, a concept, a physical product, etc.) and the creative person, the environment is seen to consist of a „domain" to which the product refers and a „field" to which the person refers (Csikszentmihalyi 1999a, b; Weisberg 2006). Unresolved problems in the domain as well as the way the experts in the field deal with these problems determine the act of creativity: on one side, by the accessibility to the (incomplete) knowledge of the domain and, on the other side, by the degree of the open-mindedness of the experts in the field. This is related to the knowledge

base and the motivation of the creative person and to the preparatory stage of the creative process mentioned above. But the domain and the field are also important „test beds“ of the results of a creative act. It will become manifest how much the domain is altered by this creative result (To what degree hitherto unsolved problems are pretended to be solved?), and the experts in the field will have to evaluate this change in the domain (Is the solution accepted? How far reaching is it?).

What conclusion can be drawn from this sketch of creativity research for dealing with ill-defined problems? (a) Before problems of this kind can be solved, a creative specification of these problems in preparatory steps is necessary. (b) Unconscious illumination, imagination, and the like are not sufficient for explaining the creative process because a necessary condition for creativity is conscious endeavors. At the core of creating something new, there is a twofold process of synthesizing ideas, facts, etc., on the one side and a transfer and transformation of these ideas, facts, etc., on the other side. (c) Insofar, as the solution of ill-defined problems requires acts of creativity, individual qualities as well as a creativity friendly environment are necessary for the problem solving process. (d) Finally, the role of a variety of cognitive elements like knowledge, motivation, and memory is emphasized.

4.1.3.2. Creative Cognition and Creative Problem Solving

The separation of personal qualities, process analysis, and environmental conditions is a useful starting point for systematizing the insights of creativity research. But from the perspective of modern cognitive psychology, this separation seems arbitrary, and therefore, attempts have been undertaken to broaden the process analysis of creativity to include at least some aspects of personal qualities and environmental conditions. Such an attempt is „creative cognition,“ developed by T. Ward, S. Smith, and R. Finke. In this approach, a new model of the cognitive process and structure of creativity is proposed, incorporating thereby the aspects of individual qualities and – though at a different level – aspects of environment (Finke et al. 1992, 1999). The main feature of this approach to creativity is a heuristic model called „Geneplore“ (Finke et al. 1992; Ward et al. 1999). According to this model, the creative process is a sequence of generative and exploratory processes (hence the name).

The *generative processes* take place in the initial phase. Here, mental manipulations of knowledge elements (retrieval, association, synthesis, transformation, transfer) lead to new

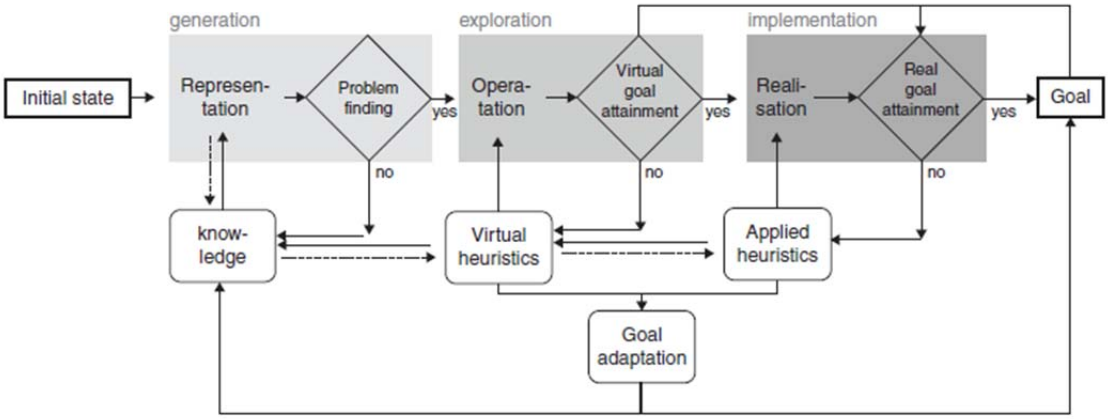
mental representations, e.g., to a new interpretation of the initial situation, new (virtual) operators, new evaluation mechanisms, and/or new combinations of these elements. Such new representations may consist of discovered patterns, mental models, and the like. These results of the generative processes are not simply novel. Rather, they have some inherent ambiguity, incongruity, and divergence and therefore encourage the investigation of these results in the second phase, the *exploratory processes*. Because the problem definition is incomplete in that no definite goal is given, the applicability and usefulness of the new representations are now tested, and if necessary, the goal is adapted.

What kinds of problems can be tackled with such new representations? Are new attributes of a problem at stake accessible? What kind of operators can be used to manipulate the initial context and what will be the result of such a manipulation? This can be summarized as a figuring out of appropriate virtual heuristics. Finding answers to these questions might include a modification (focus or expand) of the preinventive structures (new mental representations) which are the result of the generative process. Hence, multiple feedback cycles between generative and exploratory processes might be necessary until a useful novelty has been discovered.

What kind of insights for a problem solving process under the condition of an ill-defined problem can be gained from the creative cognition approach? Insights from creative cognition for the concept of problem solving are threefold: *First*, a specification of what is meant by „ill defined“ is provided. By bringing in new cognitive devices (like mental models, analogy building, context shifting, and divergent thinking; Finke et al. 1992), it is possible to specify what generative/explorative method is used. Furthermore, the following questions can be answered: Is the „illness“ of the definition due to not having a new representation or is it due to the unexplored usefulness of a new representation? Or is it due to both? *Second*, the generative processes constitute a specific determining stage of the whole problem-related process: the problem finding. This is tantamount to finding representations or heuristics by using the „Geneplore“ approach. *Third*, the problem solving itself changes character in that it becomes creative. It deals with new heuristics/operators and makes of problem solving proper a temporary operation in an overarching problem finding/problem solving feedback process. Given that, the focus of the core concept of problem solving (cf. section „The Core Concept of Problem Solving and Its Restrictions“) can be enhanced by including the phases of generation

and exploitation. Fig. 1 shows the main features of such an enhanced problem solving concept.

Fig. 1: **Enhanced concept of problem solving**



4.1.4. Applying the Problem solving Concept to the Microeconomics of Invention and Innovation

4.1.4.1. Invention as a Problem finding/Problem Solving Activity

Invention means the creation of a conceptual novelty. It denotes the creation of an idea or a concept, waiting for being applied in a practical context. Such a new idea or concept might be based on new knowledge which is simultaneously created with the invention („primary inventions“ in the sense of Usher 1971, 50), or the invention is the result of new applications of a given set of knowledge („secondary invention,“ Usher 1971, 54).

Considering invention as an act of creative problem solving means to specify the endowment of the inventor in terms of cognitive resources (cf. above section „Ill-defined Problems and Creativity Research“). A profound declarative knowledge about the domain, the ability to flexibly combine the elements of this knowledge, and knowing how to search in a given domain for new insights (procedural knowledge) is the *first* cognitive prerequisite for the creative act of invention. *Second*, the motivation for inventive activity is intrinsic in that this activity is seen (by the inventor) as an end in itself. Any environmental expectation about the result of the invention is either ignored or transformed in the inventor’s individual motivation. This means that on one side there is no person who is directly forcing the inventor to follow a predetermined action pattern; on the other side, this does not exclude that the inventor has an open mind for scientific, technical, social, or economic needs in his environment. A *third*

momentum of the inventor is a combination of all personal qualities which have been attributed to the creative personality (cf. section „Ill-defined Problems and Creativity Research“) with a special emphasis on a deliberate cognitive style and divergent thinking.

For invention, the environment hence has the double role to be a (more or less) stimulating background and to be an evaluating context. The stimulation is given in terms of scientific, technological, social, and economic „driving forces“ (i.e., strategic and/or global needs in these domains). This background for the invention process may be given by identifying „reverse salients“ (Hughes 1978, 172, 179), i.e., the bottlenecks of a global system development in the domains mentioned before. The focus on these reverse salients is determined (a) by education and expertise of the inventor, (b) by the prior activities of the inventor in the same or a similar domain, and (c) by anticipating some feasibility constraints in terms of funding, accessible R&D facilities and perhaps by referring to the expectation of an entrepreneur (Schumpeter 1983). The evaluation of the invention is one important function of the entrepreneur. This function can be incorporated in a special group of entrepreneurs, or it may be a temporary feature of actors, which have also other roles to play (as it is often the case in small-and medium-size firms). This entrepreneurial evaluation process of invented products may be influenced by the hostility of those vested scientific, technological, social, and economic interests for which the innovative development of the invention might be a threat (Nelson 1959a; Gilfillan 1970; Hughes 1978; Amabile 1998).

Given this background, the process of invention can be characterized (in a stylized manner) by referring to the features of an enhanced problem solving concept: (a) it deals with ill-defined problems, (b) it includes a stage of problem finding, and (c) it solves problems in a creative manner.

ad (a): Taking „problem space,“ „goals,“ „heuristics,“ and „operators“ as attributes of a problem definition, all these attributes can be in the state „none,“ „one,“ „multiple,“ and „vague.“ A vague problem space is given if there is a high uncertainty about the dimensions of the problem to deal with. The goals are vague if a goal is not known in a positive sense but only in a negative sense in knowing what is not intended. The heuristics and operators are vague if the appropriateness of both for any given goal is ambiguous. Then there are 4^4 possibilities to characterize the problem situation. The problem situation for an inventive activity lies somewhere between a situation which

is well defined (all attributes are in the state „one“) and a situation of total ignorance in which all attributes are in the state „none.“ The typical situation of inventive problem solving is defined, *firstly*, by a vague problem space and a vague fixing of the goals. This corresponds to the incomplete knowledge of the inventor about possible directions for transforming an initial situation and to a loose binding to the „driving forces“ of the environment mentioned above. *Secondly*, heuristics are vague and possible operators are unknown (state „none“) when the invention process starts. Hence, when the invention starts, the string of the attributes (problem space, goals, heuristics, and operators) is:

I_{vent} = {vague; vague; vague; none}.

This specific type of an ill-defined situation is called here a „strong ill-defined problem.“

ad (b): Given such a strong ill-defined problem, the first stage of the inventive process is the solution of the „problem“ of problem finding. This problem is coped with by the above mentioned generative processes (section „Creative Cognition and Creative Problem Solving“) leading to preinventive structures in terms of a specification of the problem space, mental models about this problem space, and a discovery of new (virtual) heuristics and operators for „walking through“ this problem space. Thereby, it is specified where this walk could go to, i.e., hopefully the vagueness of the goals is reduced by these generative processes. Ideally, at the end of this stage of invention, at least the problem space should be specified, and a couple of heuristics (e.g., heuristics for decomposing and for recomposing a problem space) as well as operators should wait for being explored.

ad (c): In the next stage of the inventive process, the heuristics and operators are explored. In this process, a feedback to the understanding of the problem space as well as to the goals of the whole operation takes place. One way to specify such a process more closely, is to assume that the inventor may use one of the available decomposition heuristics to discern the weakest point of a problem at stake, then he/she may solve this weakness by using an heuristic of analogy to a similar (better known) problem,

and finally, this abstract solution is adapted to the real-world problem by using a re-composing heuristic (Hughes 1978, 173).

Invention as an economic activity is confronted with strong uncertainty. This uncertainty is twofold: *Firstly*, there is no clear relationship between input and output (Arrow 1971, 172). Hence, there is a high risk of either not finding any new idea or concept at all or to find something which is not applicable, i.e., something that cannot be used as a source of innovation (output uncertainty). This side of the uncertainty can be expressed as the problem of determining the direction and amount of search activities. *Secondly*, if the invention is successful, there is no guarantee that those who are not willing to pay for the use of it can be successfully excluded (exclusion uncertainty). Partially, this uncertainty can be reduced by juridical protection (e.g., application for patent). Especially the output uncertainty confines the applicability of the usual economic calculation framework in terms of costs and (expected) yields. Invention takes place due to a strategic orientation because only in the long run a pay off can be expected. In the short and medium term, the output uncertainty as well as the motivational requirements for the inventors imply the paradox that inventive activities are the more successful, the more this activity is delinked from the normal organization of economic activities and from the efficiency criteria coupled with this normal organization (Nelson 1959a).

To resume, dealing with invention in a (broadened) problem solving framework has several specificities. It shows that invention consists of a sequence of knowledge-using and knowledge-generating stages and their feedbacks:

- It integrates modern creativity research by demystifying the „act of insight“ in that the latter is seen as a combined effect of cognitive resources, environmental conditions, and personality features. Thus, the inventive insight is not a sudden recombination or synthesis of given elements of knowledge; rather, it is a result of a – socially shaped – process of finding, defining, and treating a problem.
- The definition of this problem is influenced by a „supply push“ in terms of new knowledge and a „demand pull“ in terms of global needs. Hence, there is an „... interplay of moving frontiers of knowledge and growing need upon the direction and likelihood of success of individual ‚acts of novelty‘“ (Nelson 1959a, 107).

- Finally, in this approach, it is possible to pick up the results of those case studies related to technological inventions which are not part of the creativity research and to interpret them in a problem solving procedure.

4.1.4.2. Innovation as a Problem solving Activity

Innovation means the creation of an instrumental novelty. In many cases, it is the process of applying and thereby figuring out the result of the invention process. Generally, this figuring out has to meet two requirements: The feasibility of applying the inventive idea/concept has to be shown in technical, institutional, and behavioral terms. Furthermore, a path to the marketability of this feasible application has to be demonstrated. To deal with these challenges is at the core of the entrepreneur function.

The cognitive resources involved in innovation as a specific stage in the overarching creative problem solving process are in most parts different from the cognitive prerequisites for invention. Whereas both processes have in common that a profound knowledge of the domain is necessary (declarative knowledge), the requirement for the procedural knowledge shifts in the case of innovation toward knowing how to solve a given problem. Due to an increasing focus on applicability and solution requirements, the motivation is no more intrinsic in that the innovation is seen as an end in itself. Rather, the innovator is – at least partly – animated by strong incentives in terms of either „motivational slack“ or deficits in realizing some aspiration level as regards a given goal (March 1994).

The environment of the innovator is set by the ideas/concepts „offered“ by the inventor, the given solutions to past problems in terms of products, processes, organizations, and behaviors as well as the competitors. Compared with the inventor, the stimulation for the innovator coming from this environment is more visible (in case it is there), and the driving forces for his activity become less global and less far reaching. In such an environment, the innovator has his role as entrepreneur to play: After assessing the opportunities given by the products of the inventive process, he has to focus on one option and implement it as a midrange improvement of his market performance. This implies that there is some acceptance for what he is doing on the side of producers or consumers.

Compared with the process of invention, the process of innovation differs in the way it poses and solves problems: (a) It still deals with ill-defined problems, but the „illness“ is weaker

than in the case of invention. (b) There is no stage of problem finding anymore. (c) Solving the problems at stake requires less creativity.

ad (a): The definition of the problem is shaped by picking up the results of the invention stage. The mental representation of the problem space as well as the goals are to a certain degree specified (turning from the „vague“ to the „multiple“ state) by the invented option the innovator wants to implement and by the triggering market conditions for such an innovative activity. Hence, the following questions arise: What are the technical feasibility problems of a given concept? What qualities of the product innovation promise what kind of advantage in the market performance of the innovator? Additionally, the innovator has to deal with remaining uncertainties as regards heuristics and even more as regards operators. Although these heuristics and operators are to a large degree determined by the invented option, at least a multiplicity of these heuristics and operators have to be checked. Furthermore, the implementation of the invented option may necessitate to find out and experiment with unknown (sub)heuristics and unknown (sub)operators. Hence, the string of attributes (problem space, goals, heuristics, and operators) at the beginning of the innovation switches now to:

I_{vat} = {multiple, multiple, multiple, vague}.

This specific type of an ill-defined situation is called here „weak ill-defined problem.“

ad (b): Assuming that the initial condition for the innovative process is the application of an outcome of invention for improving the economic performance and given a weak ill-defined problem, no problem finding is necessary – the finding problem is solved!

ad (c): Solving the weak ill-defined problem of innovation still requires some creative resources. Even if heuristics and operators are determined by the option picked up by the inventor, the outcomes of these transformation procedures are uncertain. For example, which of the heuristics and operators discovered during the invention process may be appropriate for generating a desired product quality? Additionally – as already mentioned – new subproblems will arise and hence a need for new subheuristics and suboperators. Exploratory processes with respect to the whole problem at stake as well as regards the subproblems are still necessary.

Compared with the invention process, the overall degree of uncertainty is reduced. Although the implementation of an idea or a concept may be a source of additional uncertainty, the output uncertainty is reduced because the amount and direction of the search activities are much clearer now. Contrary to that, the exclusion uncertainty is increased because competitors may use the same invented option and similar heuristics and operators. Last but not least, the great challenge for the innovator is to transpose the figuring out of the invented option into a context which is determined by normal organizational procedures and economic evaluation criteria.

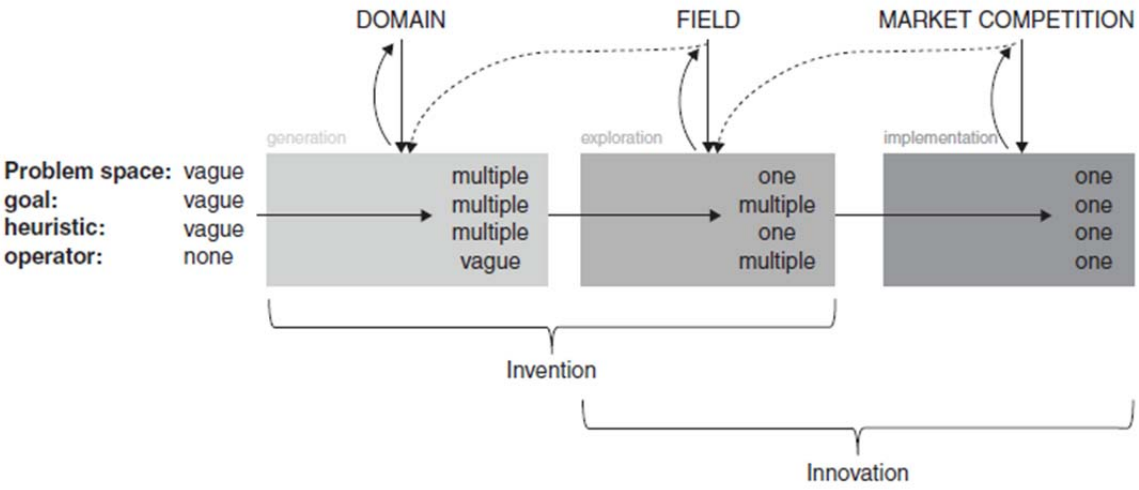
4.1.4.3. The Novelty Creating Process as a Whole and Its Embeddedness

Invention and innovation are stages of the novelty creating process as a whole (which also includes the diffusion phase (Rogers 1995)). They are distinct in terms of general definition, cognitive resources, environmental conditions, process elements, and economic character. Taking into consideration these differences, the whole novelty creating process can be deciphered by referring to the dimensions of problem solving and the social embeddedness of the latter (cf. Fig. 2). This is a process in which the state of the string of the problem representation (consisting of the components problem space, goal, heuristic, and operator) changes according to a process of „generation," „exploration," and „implementation." Starting with a situation slightly better than total ignorance in which at least some rough ideas exist about problem space, goals, and possible heuristics, the generation process leads to a reduction in the search space. It identifies different dimensions of the problem space and creates a finite number of heuristics and operators. This still very large search space is further reduced in the exploration process in which ideally a unique problem space should be found (being one condition for a switch to a well-defined problem) and possible goals of the process should be specified. The task of the final implementation stage is to find unique states for all the components of the problem representation. This means there should be definite answers to the following questions: What is the novelty about? What is it good for? What are the steps from an initial situation with a problem to be solved and a final situation, where the problem is solved?

The novelty creating process is not unidirectional (cf. Fig. 1). Because it is a process of search, discovery, and learning, there are feedbacks between the successive stages of this process (Nelson 1959b; Heuss 1965; Usher 1971). In terms of the suggested process analysis, this

means that the findings of the exploration stage stimulate new generation activities. This may be the case, either if the exploration shows that the generative activities went in the wrong direction (substitutive feedback) or if a further specification of the invention or a complementary invention is necessary (adaptive feedback). Correspondingly, it was observed in the research about innovation that „... often an innovation is changed or modified by a user in the process of its adoption and implementation“ (Rogers 1995, 174). In terms of the process analysis above, this is tantamount to a feedback from the implementation stage to the exploration stage. The reasons for this feedback are analogous to the feedback mentioned before.

Fig. 2: Features of problem solving during invention and innovation



Invention and innovation are not disjunctive stages in the novelty creating process. Rather, there is a fuzzy border between these two processes in that they overlap. The final stage of the invention process in which an idea or concept is explored thereby reducing the ambiguity of a problem representation (or discovering potential problem representations) may be the first stage of an innovation process. In this process an understanding of the invention is obtained (specifying the problem space) and the range of goals is defined to which the invention can be related.

According to the analysis of the social embeddedness of creative activities given in the systemic approach of creativity research (Csikszentmihalyi 1999a, b), these different stages of the novelty generating process are influenced by different environmental conditions. The generation phase depends on the socially available knowledge about the domain at stake

(apart from the individual tacit knowledge), whereby this domain knowledge is influenced by the new knowledge produced during the invention process in case that this new knowledge is communicated. When the generated ideas or concepts are explored and thereby related to existing ideas and concepts in the domain (including an assessment by the people in the given domain), the influence of a „field“ comes in. This is the way the inventor is affected by needs articulated in the public. Furthermore, if the field is dominated by some order parameters, there might even be an influence of the field on the direction of the generating processes of invention. As in the case of the domain, the field is influenced by the results of the inventive exploration. Finally, the implementation stage is shaped by the embedding of the innovator in the economic competition which strongly determines his goals. If a strategic deficiency in his/her competitive performance is observable for the innovator, this will have an impact on his exploration activities.

4.1.5. Conclusions and Future Research

The skepticism against the suitability of the concept of problem solving in the context of explaining invention and innovation can be relativized if this concept is enriched by integrating the insights of creativity research and modern cognitive psychology. Most of the generic features of novelty creating processes mentioned in section „Background: Microeconomics of Novelty Creation and Problem Solving“ can be explained in such a conceptual setup:

- „Generation,“ „exploitation,“ and „implementation“ can be identified as specific phases each of which combines peculiar personal, economic, and environmental conditions and gives the dimensions of problem solving different expressions.
- The successive occurrence of these phases (including path-dependence) as well as the multiranged feedback loops between them specifies the critical role of time for the novelty creating process.
- The behavior involved in such processes is not monistic; rather, it includes different modes of action especially skills, intuition, deliberation, and choice.
- Finally, the issues of acceptability and appropriation are dealt with in taking into account the „domain,“ the „field,“ and the market competition as environmental conditions.

But, by simply postulating a problem to be solved as the starting point, the boundary or trigger conditions making the occurrence of the novelty creating processes highly probable remain rather void in the concept of problem solving. To meet this explanatory requirement necessitates a broader perspective of the agency under consideration especially including the social and organizational form in which invention and innovation take place (Dosi et al. 2011; Runco 2007; Nickerson/Zenger 2004; Bijker 1987). Given this, it should be possible to elaborate the conditions favorable for the temporary passing of the agency into the ambitious and costly mode of invention/innovation (Beckenbach et al. 2012).

4.2. Behavioural Foundations of Innovation Surveys (Artikel 2)

4.2.1. Introduction

Although analysing the sources of innovation should be at the core of innovation economics, until now there has been a somewhat strange neglect of the behavioural aspects related to the innovation process. This neglect is a shortcoming of conceptualisations as well as of empirical investigations of the innovation process. The reason for that gap of research seems to be an ‚epistemological proviso' against the possibility of a microanalysis of innovation. This proviso is derived from the problem that the tangible nature and the unknown consequences of innovation make it difficult to analyse such a process. "In a sense, genuinely new ideas come out of the blue. This merely paraphrases that they are not predictable" (Vromen 2001, 199).

However, in reality, innovations do not emerge out of the blue, as firms deliberately innovate and dedicate resources (be those cognitive or monetary ones) to that purpose. The results of these endeavours, of course, sometimes might be incidental ones and are surely not completely predictable from the beginning.[51] Yet, as e.g. in the case of dedicating cognitive resources, the success of innovative efforts relies on the endowment of the firm with cognitive capacities and abilities.[52] Those cognitive resources of course can be traced back to the individuals engaged directly or indirectly in the innovation process.[53] Thus, analysing the behavioural foundations of innovation should be viewed as one main topic of innovation economics. Actually, investigating innovation from such an agent-based perspective is nothing new to innovation economics (cf. Schumpeter 1912; Katona 1951; Usher 1959; Usher 1971; Kirzner 1979; Kirzner 1997). In current research, however, besides some endeavour concerned with the behavioural aspects of entrepreneurs, this topic is not dealt with appropriate extensity and intensity.

[51] There might be, even sometimes, emerging an innovation which was not intended at all.

[52] Cf. ‚absorptive capacity' (Cohen/Levinthal 1990) and ‚dynamic capabilities' (Teece et al. 1997) as factors determining the firm's innovation activities.

[53] For a proper investigation of the (cognitive) problem-solving and problem finding processes underlying innovations, see Langley et al. (1987).

Another shortcoming of the considerations in innovation economics worth to be mentioned is that innovation is mostly not seen as a specific mode of action firms are choosing (either as a deliberate strategy or as an urgent reaction as regards to market conditions) or not. In this sense, for example, innovation and routines as two distinguishable modes of action are excluding each other, given the goal of an operation.[54] The process of selecting a mode of action (or combining multiple modes of action at the same time) is another neglected topic of innovation economics. Investigating the reasons for switching between those different modes of action, e.g., the reason why firm agents leave well-established routines and switch to a highly uncertain innovation process, is a further important aspect of a behavioural foundation of innovation processes.

Hence, agent-related surveys have their legitimate place in innovation research, since they enable a disaggregated assessment of observable innovation elements and enable to take into consideration innovation determinants which cannot be observed with the usual toolbox. These kinds of surveys shed light on how competitive market processes are picked up by individuals and transformed into different modes of action, especially to the creation of novelties. The important, but often neglected, elements between these two levels are the cognitive ‚funds' and ‚flows' of the agents in terms of knowledge, memory, attitudes and beliefs. In such a context, empirical surveys for investigating these elements are also important for theory formation (as well as they are of course influenced by the latter).

In this contribution, it will be shown how standardised enquiries[55] about innovation activities omit these agent-related topics and how they can be integrated into an empirical research design (problem of microfoundation). Corresponding to such a microperspective on innovation, it will be taken into account that the innovation process has to be differentiated in phases where agents with different cognitive as well as economic endowments and orientations interact (problem of dynamics). Hence, we join the path of innovation research initiated by Kline and Rosenberg (1986) and try to accomplish it with microeconomic or agent-based considerations. Hereby the analysis of the innovation process is confined to an eco-

[54] This is disproved neither by the possibility to routinise parts of an innovation endeavour nor by the simultaneity of departments with different modes of action within a firm.

[55] A standardised enquiry is characterised in the use of a uniform list of questions in written form.

nomic perspective: Innovation is seen in a competitive market context and has a predominantly instrumental character for the firms involved therein. We start by sketching the peculiarities of the innovation process as a background for the need of enhancing the usual design of empirical enquiries. For the agent-related enhancement, we propose to refer to Ajzen's concept of action (Ajzen 1991). For the dynamic enhancement, we refer to insights of creativity research. Both enhancements are discussed as a source for accomplishing the questionnaires used for investigating the innovation process.

4.2.2. Particularities of the research object ‚innovation' as a problem for empirical investigation

According to a prior understanding shared by many innovation researchers, innovation processes can be seen as determining, articulating and implementing novel options as regards to technology and/or product and/or behavior and/or organisation. The internal and interacting mechanisms of competition in research and markets are considered to be the driving forces behind these innovation processes. Viewed from this angle, innovation is a complex, temporary, dynamic and interdisciplinary phenomenon.

Innovation is *complex* because, although it is ‚carried out' by single agents, it has a societal impact ranging far beyond that of the horizon of the agents involved. In turn, this societal impact can more or less influence the innovators. For taking into account an agent-based perspective in a survey, this means not only to consider the behavioural aspects but also to analyse the institutional and normative influences the agents are facing. Innovation is *temporary* because the acceptance and propagation of an innovation cancels itself out and makes the novel circumstances a part of normality. Innovation is *dynamic* because the process on which it is based undergoes a transformation between the time of its beginning (discovery of an innovation) and the time of its end (social acceptance of an innovation). Therefore, the observation of innovation processes is based on a context-dependent and temporary assignment of the significance of ‚being novel' to technologies, products, processes, etc.[56] Thus empirical research has to deal with the temporality and the dynamics, in that it

[56] When looking at innovation from an economic perspective, the distinction between ‚subjective' and ‚objective' innovation becomes obvious.

allows for differentiating different stages, paths and its final acceptance. Investigating these different shapes of the innovation process faces several difficulties: the question of whether an innovation really contains something novel and is not just a reiteration of previously known options, the question where an innovation as a whole begins and where it ends and furthermore the duration of the different phases of innovation can only be answered ex post and even then not without interpretative ambiguities. To grasp these dimensions of the innovation process is a challenge for an empirical enquiry and necessitates a tricky design for the research strategy.

Finally, innovation is an *interdisciplinary phenomenon* and therefore becomes the subject matter of *different language games*. As a point of departure, the presence of an innovation can be interpreted as something ‚disruptive' taking place in technology, economy or society. In technology, this disruption is identified with a risky provision of a solution to a problem; in economics, this disruption is associated with a risky expenditure of money for the purpose of improving sales and profitability; in politics, this disruption involves a risky maintenance of the citizens' well-being. Despite this interdisciplinarity, the real agents involved in innovation are always embedded in a domain-specific context which needs to be taken into account when conducting a survey. In this respect, any survey must include the logic of the language game the agents under investigation are actually playing. This implies that the empirical research, e.g. in terms of filling out written questionnaires or interviews, requires to take care of the interviewee and their background (e.g. role in the firm). The willingness of the (potential) innovative agent to provide information is positively related to a generalised ‚mental model'[57] of innovation processes which should be comprehensible for the interviewees. This mental model comprises more than merely observable circumstances and therefore necessitates a selection by the investigator. The dilemma thus raised can only be solved by rendering transparent the model on which the survey is based and by demonstrating its suitability for building testable hypotheses and theories.

[57] This term was coined by the psychologist Kenneth Craik and is used in more recent cognitive science to denote the processing of perception, discourse and concept in everyday contexts.

4.2.3. The methodology of agent-related surveys

4.2.3.1. Overview

Neither direct observation of events, nor official statistics, nor theory-based models do suffice as a basis for explaining innovation. An instrument for bridging the gap between available data and observations relating to innovative actions, and for further establishing a connection with theoretical considerations, is provided by theory-based and modelbased surveys of (potential) innovative agents.[58]

Agent-related surveys attempt to obtain information in-between singular observations and aggregated statistical observations. The information gained is closely linked to the specific field of action of the agents involved, but it can be objectified beyond the context of the individual agents. These surveys aim to create a data collection that enables cause and effect elements to be filtered out (in formal terms: independent and dependent variables). Since the possibilities for linking the elements increase dramatically according to the number of elements surveyed,[59] it is necessary to delimit this field of study by means of theory-based hypotheses. However, such hypotheses are relatively rare in agent-related surveys on innovation processes. This indicates that these surveys remain independent from any theory-based hypothesis finding and that they are limited to the observable and easily sampled input and output indicators of the innovation process.

Although such an approach allows creating important data for complementing official statistics to be obtained, the significant factors providing an in-depth explanation of innovation processes are systematically underexposed (cf. Grupp 1998, 141; Anderson et al. 2004).

The following illustration provides an overview of the most prevalent indicators and some of their respective explanatory deficiencies (see Tab. 1: Conventional input and output indicators of innovation and their assessment).

[58] Admittedly, in contrast to official statistical surveys, there are many levels of freedom for designing and conducting such surveys. Therefore, these designs and surveys run the risk of being oriented towards the empirical or theory-related biases of the interviewer in an uncontrolled manner.

[59] If the number of parameters studied equals n, the number of their individual combination possibilities is $n(n-1)$.

Correspondingly, the following features of innovation processes are not adequately recorded in the field of empirical innovation research:

- the quality of innovation activities beyond payable and/or monetarisable variables
- the process nature of innovation activities, which is especially marked by the procedures lying between input and output and, as the case may be, becomes evident in a long incubation period for an innovative idea
- the role that agent attitudes have in the innovation process, and finally
- in that context, the significance of the heterogeneity of the agents for the course and results of the innovation process.

Tab. 1: Conventional input and output indicators of innovation and their assessment

		Type	*Assessment*
I N P U T	Innovation expenditure	R&D expenditure; Licence fees; Implementation costs; Investments.	Only monetary aspects taken into account; No correlation with results.
	Innovation potential	R&D staff; Quota of academics; Company size.	Only quantification, no qualification; Relation between agents unexplained.
O U T P U T	Patents	Patents applied for; Patents granted.	Patent utilisation not recorded; Patents only record codified knowledge; Values are branch-specific; Patenting strategies distort the results.
	Number of innovations	Number of product innovations; Number of process innovations; Number of other innovations.	Effect of product delimitation and depth of production on the number; Conditional on differentiation between major and minor innovations; Conditional on the degree of novelty of the innovation.
	Innovation success	Share of sales with product innovations; Cost reduction by process innovation; Sales and cost effects of other innovations.	Problem of the ‚incubation period' of innovations.

4.2.3.2. The ‚iceberg problem' and the ‚navigational problem' of empirical innovation research

The conventional focus on agent-related surveys thus only records a minimum of the entire innovation process (‚iceberg problem'). The processes relevant to innovation and their interrelations as well as the motivations and mindsets of the agents are not taken into account, if focusing only the visible expenditures for innovation activities and the quantifiable innovation potentials. However, both are important factors for successful innovations. These factors remain unassessed if a direct causal link is established between the input and output factors.[60] An empirically valuable hypothesis formation is rendered difficult by focusing on the visible, quantifiable (easily ascertainable) parts of the innovation process. Therefore, the iceberg problem is also linked to a scientific ‚navigation problem'.

Considering two examples of this kind of scientific navigational problem: *Firstly*, the controversy on the relevance of the supply and demand factors triggering innovation processes can be found throughout the entire range of literature on innovation theory (‚supply push' vs. ‚demand pull'). Even if these triggering factors can be monitored, it remains unexplained how they impact innovation processes and which role they play in the subjective driving forces of innovation agents. *Secondly*, it is also unclear which role potential yields play for the agents' willingness to be innovative. On the one hand, this ambiguity relates to the issue whether high or low yields enhance or decrease an agent's willingness to be innovative, and, on the other hand, it relates to the issue of what role (unfulfilled) yield expectations play as innovation triggers. Since surveys do not usually cover the attitudes of the agents involved, no empirically valuable hypotheses can be established on theses subject matters.

4.2.4. Enhancing the perspective

Taking the agents into account (microfoundation)

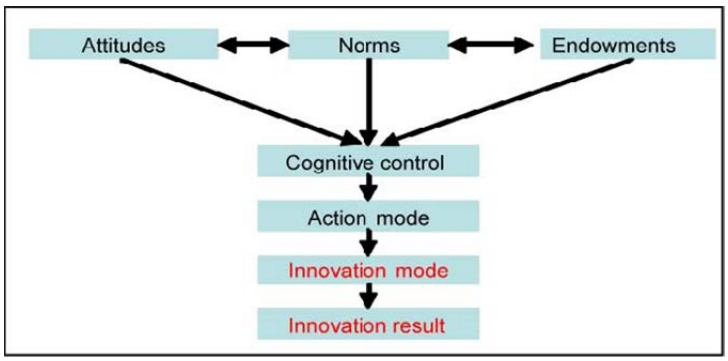
Although it would seem obvious to base innovation-economic surveys of agents (!) on the scientific understanding of agent actions and to look for a corresponding mental model of the agents in surveys, many of such surveys ignore that connection. The reason for this miss-

[60] Cf. the results of the ‚Innovation 1000' study on companies with the highest R&D budget (Jaruzelski et al. 2005).

ing link to the agents can be seen in the particular emphasis on ‚objectivity' in these kinds of surveys. Arguably, this objectivity is equated with intersubjectivity and homogeneity in order to circumvent the danger of creating a multiplicity of subjective conclusions. Furthermore, ignoring the reference to agents in innovation surveys can be explained with the lack of a suitable agent concept in economics: Searching for new options to act (as it is the case for innovation) represents a concept alien to the *homo oeconomicus*!

Nevertheless, it follows from the particularities of innovation outlined earlier that innovations represent a specific mode of action[61] of the agents involved. Negatively worded, then the agents neither follow basic routines nor simply choose from a given number of alternatives. Positively worded, the agents are in search of action possibilities unknown to them (see Langley et al. 1987; Beckenbach/Daskalakis 2003). Thus, for the purpose of including agent actions in the explanations for innovation processes, the problem arises of taking into account the information-absorbing as well as the knowledge-generating processes and the (interdependent) decision-making processes of the agents. Corresponding to the findings of

Fig. 3: Agent-related factors of innovation



cognitive and social psychology (Mumford/Gustavson 1988; Amabile 1996; Csikszentmihalyi 2001; Magee 2002; Scott et al. 2005; Kaufman/Sternberg 2006) as well as according to recent insights gained in the field of neurosciences (e.g. Dietrich 2004; Schweizer 2006; Srinivasan 2007), one cannot – in an economic context – assume that certain observable configurations in market competition directly trigger innovation activities. Instead, according to our proposal, the attitudes of the agents, their norms and their endowments play a key role in the transition into the action mode of innovation (cf. Fig. 3).

[61] The following modes of action can be distinguished: routine action, multiple routine action, choice and search action (innovation action) (cf. Beckenbach 2004).

Only few empirical studies in the older behavioural science tradition of German business administration (e.g. Biehl 1981) or some more recent studies influenced by the findings of modern cognitive psychology (e.g. Montalvo-Corral 2002) have assimilated these kinds of considerations. For the rest, agent-relevant observations show up only sporadically in the empirical literature on knowledge and innovation management (e.g. Büchner 1999; König 2000).

4.2.4.1. Actor-oriented survey design

The problem of putting a survey design inspired by these agent-related observations into practice lies precisely in the circumstance that the integration of theoretical considerations and their empirical implementation has not been done before. In this respect, a two-step procedure is called for: *Firstly*, suitable theoretical approaches for assessing innovation behaviour need to be identified; *secondly*, these approaches need to be translated into a survey design in such a way that the survey actually provides reliable measures of innovation behaviour. For that purpose, it appears suitable to resort to the appropriate models and interview techniques used in cognitive and social psychology. One such possibility is provided by Icek Ajzen's Theory of planned Behavior (TpB) (Ajzen/Fishbein 1969; Ajzen/Fishbein 1977; Ajzen/Madden 1986; Ajzen 1991; Ajzen/Fishbein 1996; Ajzen 2002; see also, Montalvo-Corral 2002, 37-49). Applying the TpB can be helpful in investigating the behavioural foundations underlying switching between different modes of action.

4.2.4.2. Conceptual foundations

At its core, TpB pertains to making the behaviour of individuals in specific contexts explainable and predictable (Ajzen 1991, 179). A distinction is made between the intention of a behaviour and the behaviour itself. The latter only takes place, if the intention is strong enough (Ajzen 1991, 181). The following three factors determine the strength of the intention: (1) The agents' attitude towards the intended behaviour, (2) the perceived social pressure to carry out the behaviour, which Ajzen designates as the social norm (Ajzen 1991) and (3) the perceived behavioural control in terms of the implementation and result of the behaviour.[62] In turn, the three determinants of intention are based on influencing factors in the form of

[62] The latter must be delimited from the possibilities actually available for behavioural control (Ajzen 1991, p.196).

multiple beliefs concerning the circumstances underlying the determinants (cf. Fig. 4). According to Ajzen, these beliefs are at the core of the TpB, since they ultimately determine the actual strength of the intentions and thus the behaviour itself (Ajzen 1991, 189). For instance, the strength of the perceived behavioral control is composed of a subjective evaluation of the perceived agent-related and factual potentials and restrictions. The strength of the perceived behavioural control's impact on the behavioral intention depends on the absolute characteristics of the determinant, but also on its relative weight compared with the two other determinants of behaviour.

Therefore, from the perspective of a TpB-based approach, an innovation can be considered as belonging to the subgroup of intended behaviour of an agent.[63] The strength of the intention ultimately determines whether an attempt is made to implement the behaviour (the innovation) and with which force this is done.

The respective variables influencing the three determinants of innovation can be characterised as follows:

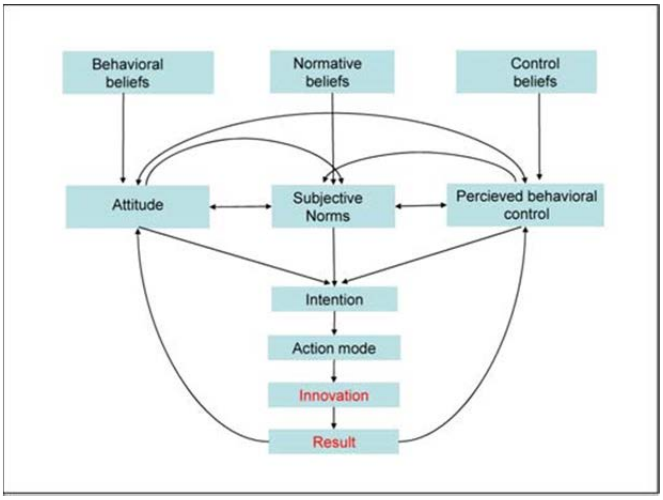
- Behavioural beliefs determine the attitude towards innovation. Behavioural beliefs can be determined by personality traits or can be based on the subjective assessment of a behaviour's potential result.
- Normative beliefs pertain to the extent that the innovating agent believes that the internal and external environment expect innovative behaviour from him/her.
- Control beliefs are related to a subjective evaluation of those capabilities required for carrying out innovation.

If due to the expression of the behavioural components an innovation takes place, the innovation results are fed back to the original conditions.[64] In this context, the strength of the intention again plays an important role: the selection of the mode of action is dependent on the strength of the intention (i.e. it does suffice for transitioning into the innovation mode) as well as the strength of the intention has an impact on the efforts undertaken to implement the innovation (cf. Fig. 4).

[63] The other group is non-intended behaviour such as habits, routines, etc.

[64] This dynamical perspective is alien to the original TpB concept.

Fig. 4: Extended ‚Ajzen model' of innovation behaviour



4.2.4.3. Operationalisation

Which variables can serve to depict innovation behaviour? In the field of psychology, there are item batteries available for the purpose of assessing specific personality traits which can, for all intents and purposes, be transferred to economic circumstances (cf. Daskalakis/Krömker 2007). Furthermore, it will surely be a desideratum for the economics of innovation to develop these kinds of items in the near future. Several examples, the systematic of which adhere to the extended Ajzen model, are: (1) selecting the mode of action, (2) intention and (3) beliefs,[65] which are summarised below.

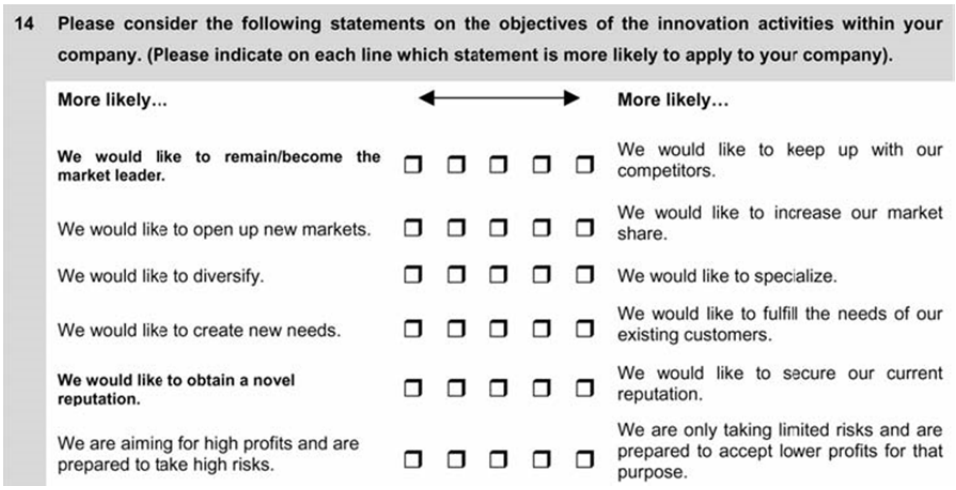
1 *Selecting the mode of action*: This item allows questions to be specified concerning the processes for determining a certain mode of action (Who is involved? Who is making the decisions? What are the reasons for a certain decision?). With regard to the seminal findings of March and Simon (1958), the role of the aspiration level and the strategic targets for decision-taking should be evaluated.[66] For that purpose, the underlying economic (general) objectives (such as profitability safeguarding/ enhancement or safeguarding/increasing market share) should be distinguished from the potential reasons (specific objectives) for current innovation activity derived therefrom. Either they can be of a stra-

[65] Prior to selecting the variables, it should be clarified which actor level is targeted by the survey: Is it oriented towards the company as a whole or is the individual filling out the questionnaire the scientific object of study?

[66] An attempt to synthesise the approaches of ‚Ajzen' and ‚March and Simon' for explaining the triggering conditions for innovations is made by Beckenbach et al. (2007b).

tegic nature (‚leadership' in various dimensions), or they will be tactical reactions to market demands observed, such as client requests. Fig. 5 provides an example of this type of target-related questionnaire.

Fig. 5: **Assessing the selection of mode of action in the questionnaire for the ‚second-order innovation' project**



14 Please consider the following statements on the objectives of the innovation activities within your company. (Please indicate on each line which statement is more likely to apply to your company).

More likely...		More likely...
We would like to remain/become the market leader.	❐ ❐ ❐ ❐ ❐	We would like to keep up with our competitors.
We would like to open up new markets.	❐ ❐ ❐ ❐ ❐	We would like to increase our market share.
We would like to diversify.	❐ ❐ ❐ ❐ ❐	We would like to specialize.
We would like to create new needs.	❐ ❐ ❐ ❐ ❐	We would like to fulfill the needs of our existing customers.
We would like to obtain a novel reputation.	❐ ❐ ❐ ❐ ❐	We would like to secure our current reputation.
We are aiming for high profits and are prepared to take high risks.	❐ ❐ ❐ ❐ ❐	We are only taking limited risks and are prepared to accept lower profits for that purpose.

Note: For a full range of interpretation of this questionnaire and the results of the enquiry, cf. Beckenbach et al. (2007b) and Beckenbach et al. (2007a, forthcoming).

Source: Available online at: http://www.uni-ris.de/eng/index.html

2 *Intention*: For this item, it is necessary to ascertain whether innovation activities will take place (within a time frame yet to be specified) in the future. This has already often been incorporated into questionnaire designs. Nevertheless, for a questionnaire adapted to the Ajzen model, the strength of the intention has to be included as well.

3 *Beliefs*: This item includes the three dimensions of beliefs according to the TpB.

- *Behavioural beliefs*: Possible variables are personality traits such as the willingness to experience novel situations or to take risks, and issues regarding the assessment of the result of a certain behaviour obtained, for example, by subjectively evaluating a competitive situation.
- *Normative beliefs:* The questions can address either firm-internal social norms (corporate culture, staff expectations, corporate objectives (e.g. market leadership)) or the perceived external norms (e.g. reputation in the area, client/subcontractor/political demands).

- *Control beliefs:* The variables to be taken into account can include the estimation of (personal and financial) resource availability, but also the assessment of one's personal innovation-relevant capabilities (e.g. the ability to solve problems, know-how, skills, managerial qualifications (cf. Beckenbach/Daskalakis 2003)). Furthermore, standard variables, such as the number of staff engaged in R&D or R&D expenditures, must certainly be classified under this category of beliefs.

Since the variables outlined above are meant to assess personality traits, it is recommended to resort to the standard scaling procedures when formulating the questions regarding scaling, such as the ones used in psychological personality research. At the minimum, Likert scales should be used to determine the strength of intention and beliefs. Furthermore, in order to measure beliefs, it is particularly meaningful to form semantic differentials (cf. Ajzen 2006, 5). Incidentally, it is recommended to implement at least one control question for each item.[67] A concise example of this kind of survey in the form of semantic differentials is provided in Fig. 5. It refers to several elements for evaluating corporate behaviour (and not to the personality of the person filling out the questionnaire).[68]

4.2.4.4. Taking time into consideration (dynamic foundation)

Innovation research striving to obtain extensive explanations cannot focus exclusively on the propagation of technically mature novelties on markets. Corresponding to the discussion initiated by Schumpeter, innovation research must also include the entrepreneurial function as the core area of the innovation process. In the age of fundamental research spurred on by public institutions and when taking into account the systematic exploration of innovation potential within the R&D departments of major companies or among providers of specialised services, it is essential – and this is what extends beyond the Schumpeterian perspective – to include the invention as the early phase of the innovation process in the explanatory perspective. The systematic organisation of such invention processes sets the course for further

[67] For evaluation-technical reasons normally three or more control questions are incorporated into the design of psychological questionnaires. Since interviewees in innovation-economic questionnaires are, as a rule, involved in the economic process and have only a limited amount of time to fill out the questionnaire, the number of control questions should be adapted to the extent of the questionnaire as a whole (cf. Daskalakis/Krömker 2007).

[68] The study by Daskalakis and Krömker (2007) also contains a comprehensive conceptual and empirical analysis of both aspects.

innovation processes. According to the diversity of the tasks at stake, the boundary conditions and the staffing during the phases of invention, innovation and diffusion, the innovation process as a whole displays a dynamic character. Both the development dynamics in the different phases and the combination of these phases by means of transmitter mechanisms and feedbacks have a distinctive impact on the innovation results (cf. Kline/Rosenberg 1986).

The Ajzen approach, as described above, is helpful to investigate those behavioural variables which influence the decision to innovate. What cannot be accomplished on the basis of TpB is analysing the dynamics of the innovation process and therewith the foundations of invention and innovation. For this topic, modern cognitive theory provides useful insights.

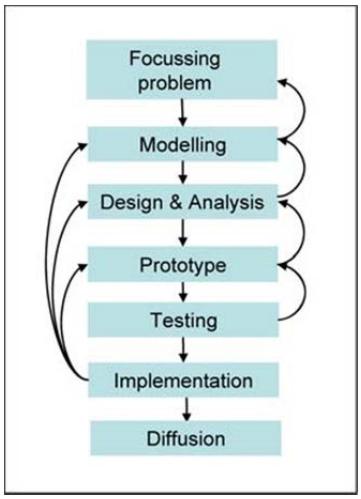
At least, since the Simon (1977) study, a distinction has been made between ‚ill-defined problems' and ‚well-defined problems'. The concept of problem solving describes processes which start with a known problem of stake and analyses the different heuristics and (cognitive) operators being used while trying to solve the problem (Newell/Simon 1972). Problem finding might occur before the process of solving a problem and describes the heuristics and (cognitive) operators agents use to discover and to shape the focus of problems.[69] For both processes, cognitive features as well as relevant skills are well described in the cognitive sciences, especially in creativity research (e.g. Finke et al. 1992; Csikszentmihalyi 2001). Therewith, four distinguishable behavioural aspects relevant for both processes can be identified: *knowledge* (declarative and procedural), *skills* (in terms of finding new heuristics and capabilities for recombination and association of given elements of knowledge), *motivation* (intrinsic and extrinsic) and *personality features* (e.g. curiosity, steadfastness of purpose, risk acceptance) (cf. Beckenbach/Daskalakis 2003).

Within the phase of the invention, being characterised as ‚an ill-defined problem' (Langley et al. 1987; Beckenbach/Daskalakis 2003), a distinction can be made between the identifying and focusing of the problem addressed, the concept development and the modelling of the design resulting therefrom. The innovation phase, representing the stage of ‚well-defined problems', in a narrow sense, starts with the development of a prototype resulting from the design and consists of testing and, if necessary, modification. This is the basis for working out

[69] For a broader discussion, cf. Langley et al. (1987), Klahr/Simon (1999) and Beckenbach/Daskalakis (2003).

a configuration that can be implemented. Should this implementation prove a success, it will be taken over by other agents and in this respect become a point of departure for a diffusion process (cf. Fig. 6).

Fig. 6: Phases of the innovation process



The initial conditions (such as financial resources, personal abilities, cognitive orientations and the available knowledge) have the same impact on the development of the innovation process as the type of connection between the above-mentioned phases. Empirical studies have shown that the types of problem definition, the search strategy, the extent of the search and the heuristics as well as paradigms used therewith are of decisive importance for the search result (cf. Biehl 1981, 76; König 2000, 40). A priority for empirical innovation research lies in obtaining general findings on the correlation between the processing and the success of the innovation concerned. The resulting path dependency of firm-specific innovation processes has been brought up in the field of innovation economics only within the context of evolutionary approaches.[70] The processing issue of innovation is also partially addressed and empirically investigated in the framework of the business management literature on innovation management under the heading of process monitoring (cf. Hauschildt 2003, 450) and interface management (cf. Salomo et al. 2003, 161). However, in the mainstream of empirical innovation research, the dynamics of the innovation process are barely discussed.

[70] Cf. David (1985) for an early conceptualisation and Vincenti (1990), Helfat (1994) and Gürtler/Valentin (2004) for exemplary empirical studies.

When conducting agents-related surveys, the dynamics of the innovation process can be taken into account in three ways: *Firstly*, by explicitly enquiring about path dependencies. Questions might be addressed in the following areas:

- What is the average share of time being invested in invention and innovation?
- Did this share increase or decrease within the last number of years (to be specified)?
- Which resources were used for the innovation process?
- To which extent did the problem description underlying the innovation change during the innovation?
- Were the specified search routines complied with?
- When was a specific innovation path determined?
- Did the costs for the transition to another search path play a role?

Tab. 2: **Graphic representation of the distribution of innovation activities over time**

Implementation								■
Test						■	■	
Prototype					■		■	
Design			■	■			■	
Model		■						
Problem focus	■	■						
Time								

Secondly, by taking into account the relevant cognitive resources and, moreover, the relevant managing instruments, which are implemented to foster the propensity to innovate. Examples for possible areas of questioning are:

- Which kind of cognitive resources were used in the different steps of the innovation process?
- Which kind of external (cognitive) resources were used to what extend to complement the innovation process?
- Which knowledge- and/or innovation-management tools are used in the different phases of innovation?
- What kind of agent-related factors hinder the innovation process within the firm?

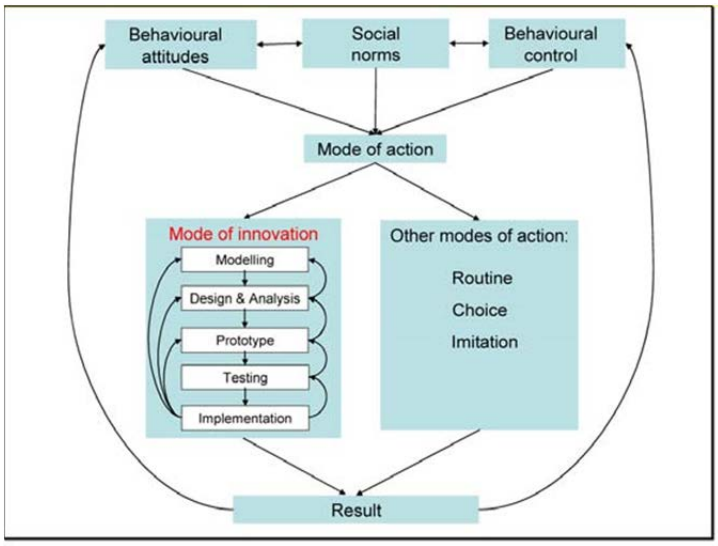
Thirdly, the dynamics of innovation can be assessed by a project-related breakdown of innovation activities over time, e.g., using a bar chart representation (see Tab. 2).

4.2.5. Integrating behavioural foundation and the dynamics of innovation

The previous considerations can be combined to the concept of an agent-based view of innovation dynamics. In this concept, the external (competition-related) and internal (cognition-related) prerequisites for innovation action are specified, and the time requirements of the innovation determined by the sequence of phases as well as path dependency are itemised (cf. Fig. 7).

This kind of integration is based on the assumption that the TpB can be used in a twofold manner. On the one side, it is an appropriate framework for approaching the problem of a behavioural foundation of innovation processes. A specific combination of excessive control capabilities, embeddedness in a social or competitive pressure and explorative attitudes may explain the triggering of innovation processes on the agent level. This can be accomplished by the research about the sources of creativity which itself enables the integration of phase specificity into the analysis of the innovation process.

Fig. 7: **Agent- and time-referenced innovation process**



On the other side, beyond this innovation-specific constellation control abilities, norms and attitudes in their varying expressions can also explain other modes of action, including those which are not coupled to the activation of an intention (like routines and habits). In this respect, the TpB can be combined with research results about the dichotomy of automatic and

deliberate behaviour and the corresponding problem of cognitive control (cf. Camerer et al. 2005, for an overview).

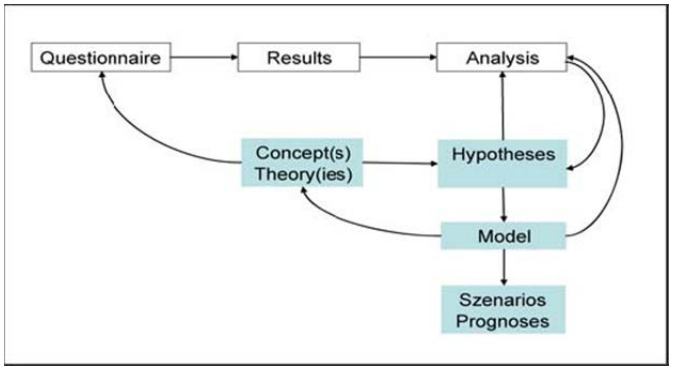
Taking into account the competitive market as the embedding process for the interrelation of the behavioural elements in the enhanced TpB concept, the following implications can be derived from this concept:

- (Research and market) competition as the driving force for innovation must be interpreted as an agent-specific, path-dependent processes.
- The thereby produced heterogeneity in the willingness to innovate and in the innovation processing among the various agents or groups of agents is likewise reduced by competitive balancing processes such as knowledge transfer, imitation and acquisition.
- This interaction between the societal, competitive and the individual dimension of the innovation process can be characterised in more detail by establishing a typology of agents and a typology of competition. For instance, one type of agent can be characterised in that he/she features a combination of pessimistic expectations, a reactive innovation objective and a loyalty to paradigms, while one type of competition, for example, can feature a low degree of concentration, low entrance barriers and the orientation towards the dimension of cost.

The hypotheses explicated in the concept itself as well as the above-mentioned implications should then be used for relating the survey data to each other and to determine the corresponding (in)significances. The results thus obtained could lead to a modification of the hypotheses themselves.[71] Such ‚empirically saturated' hypotheses become the subject matter for the formation of a model which needs to be tested in its entirety in terms of its ability to reproduce the results of the survey and, therefore, potentially provides a reason for modifying the concept. The model and concept specification arising from this comparison with the results of the survey is subsequently used in the case of repeated surveys to improve the questionnaire. In this manner, agent related surveys and model formation are linked to each other (cf Fig. 8).

[71] For example, in the context of a cluster analysis, the actor-related survey results can be used to render the significant agent attributes clear.

Fig. 8: **Combining agent-related surveys with the development of theories and models**



The above-mentioned scientific navigational problems (cf. Subsection 3.2) can also be treated in the framework of such an interaction between agent-related surveys and model formation. This can be illustrated using the example of the supply push vs. demand pull controversy. In this context, there is a multitude of factors which lie between the scientific-technical potential, the factor prices and the regulatory incentives on one side, and the individual and/or societal change of preferences on the other side. Such a multitude of internal factors transforms the external innovation driving forces into the willingness to innovate and/or factual innovation action. In particular, such internal factors can be specified as the attitudes of the strategic decision-takers and as the absorptive and creative potential of firms including the path dependencies triggered by these factors. From this perspective, the external (demand or supply) factors are necessary, but not sufficient conditions for the implementation of innovations. Only specific configurations of the internal factors generate the response required for innovation to take place. Thus, it can be assumed that – in compliance with the phase differentiation of the innovation process – the two exogenous forces driving it have a process-dependent importance for this innovation process: At the outset of the innovation process, the supply factors are more significant; towards the end of the innovation process, the demand factors gain more importance. In order to study these and other issues surrounding the innovation process, the tool of an agent-related survey remains indispensable!

4.2.6. Discussion and conclusions

The starting points of our analysis have been two shortcomings in the analysis of innovation processes: the missing behavioural foundation and the neglect of the time dimension. We propose to remedy these shortcomings by figuring out a broader conceptual framework for the analysis of innovation. As to the behavioural foundation, the conceptual enhancement

was based on the TpB of Ajzen; as to the time dependence, the conceptual enhancement was tackled by referring to the seminal contribution of Kline and Rosenberg on the one side and the insights of creativity research on the other side. Based on that, our aim was to specify how these conceptual enhancements of innovation research can be used in the design of questionnaires for empirical enquiries. Hence, the conceptual ideas are prepared for being submitted to empirical validation, and by this they are possibly modified or even rejected.

If these conceptual ideas come through their empirical ‚baptism of fire', an augmented explanatory power of innovation theory can be expected. *Firstly*, innovation activities are not simply just there or the result of exogenous shocks, but rather explainable in terms of behavioural triggering conditions (which itself are a kind of behavioural translation of the market competition[72]). This includes taking other modes of actions into account from which the agent who is willing to innovate in most cases starts.[73] *Secondly*, path dependencies of the innovation process as a whole can be analysed. This is not confined to the diffusion phase of an innovation but includes the invention phase and the innovation proper. How the different phases of the whole innovation process are linked to each other does not only explain the time needed but might also explain the reason for the failure of an innovation.

[72] Hence, the market conditions itself are necessary but not sufficient for explaining the occurrence of innovations.

[73] The only exception is a start-up firm developing an innovative idea.

4.3. Behavioural Determinants of Eco-Innovation. A Conceptual and Empirical Study (Artikel 3)

4.3.1. Introduction

Given the burdens imposed on natural resources by global economic activity, analysis of the determinants of companies' eco-innovative behaviour has become an essential line of research within empirically orientated ecological economics. When addressing these matters in research, reference is typically made to the approaches and indicators utilised in innovation economics as set forth in the Oslo Manual (OECD and Eurostat 2005) and supplemented by the specifics of eco-innovation (Kemp and Pearson, 2007 and OECD, 2010).

The application of these approaches and indicators from innovation economics has, however, been subject to various problems which may in turn explain why the findings of empirical eco-innovation research are relatively heterogeneous and in some cases even contradictory (e.g. Bernauer et al., 2006; Kammerer, 2009). These problems are two fold. First of all, empirical innovation research provides a well-defined set of indicators, but some of these have long been known to have inherent drawbacks that limit their explanatory power. This is the case, for example, with research and development (R&D) indicators and with patent indicators (e.g. Griliches, 1990 and Kleinknecht et al., 2002). Secondly, there is one significant area of knowledge that is not systematically considered in this approach, namely the agent-based analysis of the behavioural determinants of companies' decisions to undertake innovations.

The adoption of a restricted analytical perspective of this sort has two specific limiting effects. On the one hand, it limits the potential to evaluate eco-innovative activity as a specific behaviour of market players, and, therefore, restricts the potential to gain a more complete understanding of the conditions in which companies actually do decide to undertake eco-innovation. On the other hand, it limits the analysis of the (prospective) effects of regulations on eco-innovative behaviour. As we confront these limitations, the question arises how it might be possible to outline a behavioural conception of eco-innovation and what theoretical approaches could be used in undertaking this task.

This is the starting point for the present study. The aim is to make a theoretically and empirically grounded contribution to eco-innovation research that is based on a behavioural per-

spective. The empirical question that will be addressed in this connection concerns the behavioural determinants affecting German suppliers to the automobile industry as they decide to undertake environmental product innovations. This study focuses on a specific type of eco-innovation, i.e. the sustainable product design of automobiles set out in article 4(1) of the European Union's 'End-of-life Vehicles Directive' (ELVD). The behavioural foundation of this analysis is realised by making use of the Carnegie School's 'Theory of the Firm' through the application of a concept included in that theory called the `Concept of Initiation´. This concept explicitly incorporates a behavioural perspective with respect to the factors influencing the decision to innovate.

The study is organized as follows: Section 4.3.2 briefly summarises and explains the background of the Carnegie School's Concept of Initiation. Section 4.3.3 provides an overview of the economic sector under consideration in the study and the specifics of the regulation in focus. In section 4.3.4, the Concept of Initiation is reformulated as the 'Composed Eco-Initiation Structure' (CEIS), and the hypotheses to be tested are developed thereby making reference to findings of empirical innovation research in general and of empirical eco-innovation research in particular. Environmental management research factors are taken into consideration as well. Sections 4.3.5 and 4.3.6 are devoted to the empirical analysis of the data obtained and to presenting the dataset, method and results. Section 4.3.7 closes this article with a discussion and outlines recommendations for further research and for the design of environmental policy instruments.

4.3.2. Behavioural aspects of the decision to innovate

4.3.2.1. Background

Within the framework of traditional economics, the concept of the *homo oeconomicus* is the dominant concept of behaviour. It is certainly beyond dispute that this concept does not reflect reality and therefore offers limited access at best for an empirically based analysis. Indeed, by exploring the deficiencies of the concept a new field of economic research known as behavioural economics has been created. This branch of research, however, is usually confined to the experimental analysis of specific cognitive processes which run counter to the concept of rationality (e.g. Kahnemann, 2011; Thaler and Sunstein, 2009), not taking into consideration more complex behaviour such as the behaviour of and within firms.

In keeping with this new behavioural orientation, efforts have been made to adjust environmental economics accordingly (e.g. Buenstorf/Cordes, 2008; Faber et al., 2002; Gowdy and Erickson, 2004; Shogren et al., 2010). In this context, an increasing number of studies analyse the effect of regulations on the basis of insights from behavioural economics (e.g. Gsottbauer and van den Bergh, 2011; Reise et al., 2012; Robinson and Hammit, 2010; Venkatachalam, 2008). The OECD is also currently launching a related project.[74] However, in this connection it has not yet been possible to identify any clear concept of economic behaviour of the individual agent and still less a concept that could be generally applied to the eco-innovative behaviour of firms.

A behaviourally grounded approach analysing the innovation activities of firms can, however, be found in those branches of innovation economics that are associated with evolutionary economics (e.g. Dosi, 1988; Nelson and Winter, 1982; Witt, 2009), although most of these works are not related to ecological matters (but see e.g. Foxon 2006; Montalvo-Corall (2002); van den Bergh 2007). A common feature in this literature is the reference it makes to the Carnegie School's concept of the behaviour of individual agents and firms. But attention has not been paid to one key aspect of the Carnegie School approach, namely the Carnegie School´s Concept of Initiation. This concept and its application to eco-innovative behaviour is the subject of the present study.

4.3.2.2. The Carnegie School's Concept of Initiation

The concept of the 'initiation of innovation' is embedded in the 'theory of the firm' as developed by the Carnegie School.[75] The theory is based on an approach informed by cognitive and social psychology that the authors explicitly regard as a (more realistic) alternative to the neoclassical concept of economic behaviour. The best-known features in this context are the assumption of bounded or procedural rationality and the concept of "satisficing" as an alternative to the concept of perfect rationality and optimisation. The aspects of behaviour exam-

[74] http://www.oecd.org/env/consumptioninnovationandtheenvironment/behaviour.htm; last accessed 7.11.2012.

[75] The term 'Carnegie School' refers to three-year-long collaboration between Richard Cyert, James March and Herbert Simon at the 'Carnegie Institute of Technology'. Simon's early work, 'Administrative Behavior' (1997/1947) as well as 'Organizations' (March and Simon, 1993/1958) and 'The Behavioral Theory of the Firm' (Cyert and March, 2001/1963) are considered to be the seminal works of the Carnegie School.

ined by the Carnegie School are relatively broad; one prominent focus, however, lies in the tension between "action and inaction" or between "persistence and change" (March and Simon, 1993, 195), which can also be understood as a tension between routine and innovation.

In this context, the Carnegie School drew a fundamental but little-noticed distinction early on between the process of the decision to conduct innovation, on the one hand, and the process of innovation proper, on the other. In particular, March and Simon were concerned with the former, presenting this for the first time as the 'Concept of Initiation' in 'Organizations' (1993). The following outline of three core components of the concept is to be understood as a summary of the aspects discussed in 'Organizations' and the subsequent works of the Carnegie School (see for the following as far as not mentioned otherwise in this section, also Cyert and March, 2001; Simon, 1993, 1991, 1964, 1963).

The first core component of the Concept of Initiation is the **goal-orientation of corporate behaviour**. The Carnegie School differentiates between aggregated and constitutive overall goals, such as turnover, profit, sales, company size, market share and satisfaction of customer needs, on the one hand, and operative goals that serve to implement these, on the other hand. It is assumed that goals adapt to internal and external changes in conditions through learning processes and that new goals can arise in this process. It is furthermore assumed that companies form aspiration levels for each goal within a given time period and then compare this with the level actually reached or anticipated in the following time period. If the discrepancy between the desired and attained/anticipated target height is too great, and if lowering the target height to the level most probably attainable is not satisficing, a search process for innovation opportunities is conducted with the expectation that the desired aspiration level will be reached when these innovations are realised (for more detail see Beckenbach et al., 2012).

The second core component is the **integration of the corporate environment into the decision-making context**. The Carnegie School assumes that continuous engagement with the environment is necessary to identify problem areas that might jeopardise existing goals and/or require the development of new goals. The problem areas mentioned here are current or anticipated demands of, or changes in, the environment. The environment includes shareholders, customers, service providers, suppliers and state institutions. Examples of envi-

ronmental demands include customer wishes, regulatory enforcement and social pressure. Environmental changes are manifested, for example, in the competitive structure, technological progress, and uncontrollable "external shocks" (Cyert and March, 2001, 118).

The third core component encompasses the **characteristics of agents relevant to decision-making and corporate conduct in the context of bounded and procedural rationality**. Thus, for instance, the willingness to engage with processes of change to address perceived problems is determined by the general attitude towards innovation. Furthermore, individual traits and behavioural characteristics, such as risk taking, experimentation, creativity, and flexibility are of relevance for the decision to innovate (March, 1991; Simon, 1999, 1985). Additionally, the degree of specific expert knowledge built up over time, corresponding experiences in the past (Simon, 1999) and the nature and extent of the monetary resources available (e.g., in terms of slack) are important in this context.

The interplay of these three components characterises the nucleus of the Concept of Initiation, and the initiation of innovation is thought to be a process that begins with the perception of a problem that seems to endanger currently existing goals and ends with the (strategic) decision for or against undertaking innovation. Depending on the particular situational problem and on agent specificities, heterogeneous decision-making patterns may emerge.

4.3.3. Sector and regulation

The automotive industry is one of the most important business sectors worldwide. The production of passenger cars continues to be an essential part of this industry; in 2010, approximately 15 million passenger cars were manufactured in the European Union, with 5.5 million of these coming from Germany (ACEA, 2011). However, it is generally acknowledged that the sector has been hit hard by the financial crisis, which reinforced consolidation processes resulting from increasing competitive pressures that have long been discernible in the automotive industry (European Commission, 2012). These pressures are manifested in the growing concentration among original equipment manufacturers and suppliers and in a decreasing vertical integration of production processes, including a shift of R&D processes to suppliers (Proff, 2011). Thus, suppliers to the automotive industry are playing an increasingly important role in the overall market.

A counterpart to the production of automobiles is the disposal of the produced vehicles after usage. The European Commission assumes that Europe generates approximately eight to nine million tons of waste in the form of old vehicles every year;[76] in Germany alone, the figure in 2010 was 516,128 tons, according to Eurostat.[77] The corresponding waste management process is regulated in the European Union by the 'End-of-Life Vehicles Directive' (ELVD) (European Commission 2000). In article 4(1), the ELVD imposes the following:

> "In order to promote the prevention of waste, Member States shall encourage, in particular: (a) vehicle manufacturers, in liaison with material and equipment manufacturers, to limit the use of hazardous substances in vehicles and to reduce them as far as possible from the conception of the vehicle onwards, so as in particular to prevent their release into the environment, make recycling easier, and avoid the need to dispose of hazardous waste;
>
> (b) the design and production of new vehicles which will take into full account and facilitate the dismantling, reuse and recovery, in particular the recycling, of end-of-life vehicles, their components and materials;
>
> (c) vehicle manufacturers, in liaison with material and equipment manufacturers, to integrate an increasing quantity of recycled material in vehicles and other products, in order to develop the markets for recycled materials."(ebd.)

Article 4(1) of the ELVD thus explicitly links two areas that occur at the beginning and end of the motor vehicle life cycle, namely product development and product recycling (Mazzanti and Zoboli, 2006). The ELVD does not, however, specify how article 4(1) is to be implemented. Clearly, this regulation appears to be more of a request than an obligation; this is also evident in the German implementation of the ELVD, the 'Altfahrzeugverordnung' ('End-of-life vehicles ordinance')[78].

In light of extent suppliers to the passenger car industry are taking the provisions of article 4(1) of the ELVD into account, and further, what are the determinants governing this behav-

[76] http://ec.europa.eu/environment/waste/elv_index.htm; last accessed 22.10.2012.

[77] http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home; last accessed 22.10.2012.

[78] http://www.gesetze-im-internet.de/bundesrecht/altautov/gesamt.pdf; last accessed 22.10.2012.

iour. The aim of the following sections is to examine whether an application of the Carnegie School's Concept of Initiation can help in providing answers to these questions.

4.3.4. Specification of the 'Composed Eco-Initiation Structure' and hypotheses

4.3.4.1. The 'Composed Eco-Initiation Structure'

To make the initiation model empirically accessible, three premises were taken collectively as the basis for its application. First, eco-innovative activities were interpreted as specific sub-areas of companies' 'normal' innovation activities. Second, following Fishbein and Ajzen (1975) and Ajzen (2005), it was assumed that an intention to act represents the decision to undertake an action, and that analysing the determinants of such an intention allows more distortion-free results than analysing the determinants of a past action. With this in mind, the specific type of eco-innovation to be investigated represents the extent to which suppliers in the passenger car industry intend to pursue, and expend resources on, product developments relating to article 4(1) of the ELVD in the context of general product innovation activities over the next five years. The object of investigation in the present study thus differs from that found in most other empirical studies on eco-innovation because these typically focus on past eco-innovative activities, not on future actions (but see Corral, 2003).

Third, it was assumed that there are environmental goals within a company's set of goals to be identified and that the relative importance of these goals determine the decision to conduct eco-innovations. As stated in Section 4.3.2.2 above, the goals of a firm play a dominant role in the decision to innovate. However, focusing only on the economic goals typically referred to by the Carnegie School would be inadequate for this study. If goals are determinants of a decision to innovate in general, then we must ask to what extent the decision to undertake an eco-innovation in particular is based on corresponding objectives, i.e., environmental goals, and why and to what extent firms develop environmental goals. Furthermore, two specific types of goal are distinguished that correspond to the Carnegie School's distinction between constitutive goals and operative goals: general environment-related goals and operative environment-related goals. In the context of this study, these operative goals have been identified in the stipulations of article 4(1) ELVD. This accords with Porter and van der Linde (1995), who assume that sufficiently stringent regulations may lead to a specification of goals in relation to the contents of eco-innovations.

The interplay between the two types of environmental goals and the specific type of eco-innovation focused upon in this study is summarised in the following as the 'Composed Eco-Initiation Structure' (CEIS), which is depicted by Hypothesis 1 as follows:

H1. Environment-related goals have a positive effect on eco-innovative intentions (H1a). General environmental goals affect the intensity of regulation-specific environmental objectives (H1b). These objectives, in turn, have a stronger effect on eco-innovative intentions than general environmental goals (H1c).

In keeping with the structure and complexity of the Concept of Initiation and its emphasis on the relevance of goals for the decision to innovate, the following section (4.2) relates each of the subsequent hypotheses to all three variables of the CEIS.[79]

4.3.4.2. The determinants of the 'Composed Eco-Initiation Structure'

In the following, the (possible) determinants of the CEIS are derived from the Concept of Initiation by adapting relevant aspects of its three core components. Altogether, four aspects are considered: (i) the attitude towards (eco-)innovation (third component), (ii) the relevant resources (third component), (iii) 'hard' economic goals (first component) and (iv) the effect of market conditions and of external shocks (second component). Fig. 9 shows the structure of the CEIS and the determinants under consideration, differentiating between those related to innovation in general and those related to the specific type of eco-innovation investigated in particular. This differentiation will be of relevance with regard to interpreting the results of the statistical analysis in Section 4.3.6., but is not expedient in outlining the hypotheses in this section.

(i) With respect to the attitude toward (eco-)innovation, the following two assumptions are made with regard to the CEIS: first, that attitudes towards innovation in general and eco-innovation in particular determine the form and relative importance of environmental goals and of eco-innovation goals; and second, that attitudes may be represented via a corresponding classification of types of agents, particularly in terms of whether their environmen-

[79] Thus, both variables concerning goals are as well endogenous as exogenous variables; this is possible because of the chosen statistical method (see Section 4.3.5).

tal-related behaviour tends to be pro-active, reactive to, or independent of legislation. Hypothesis 2 (H2) summarises these aspects as follows:

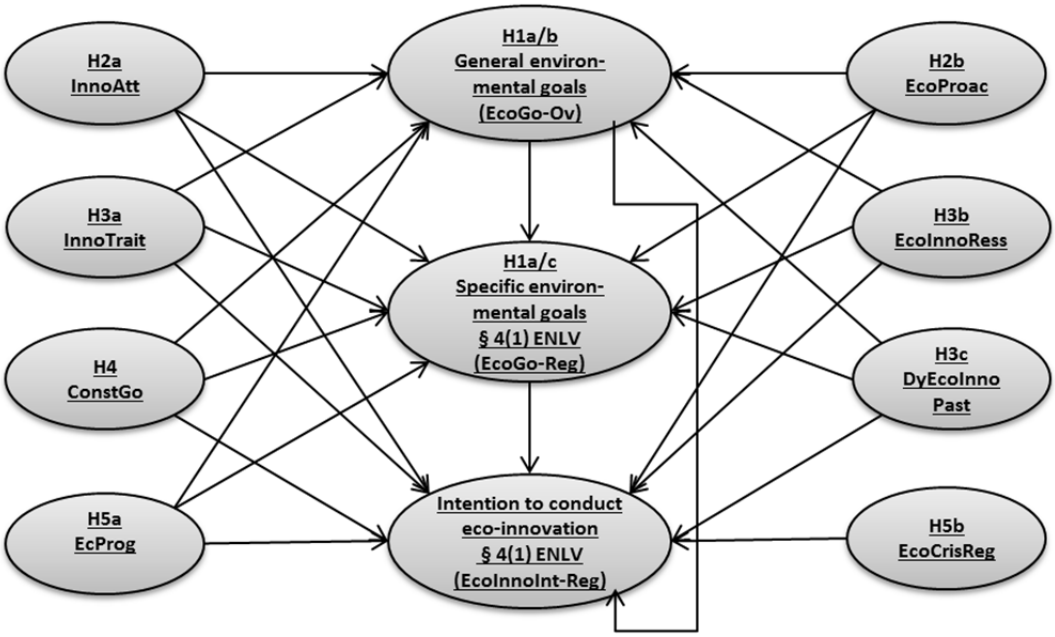
H2. The attitude toward innovations in general (H2a) and the specific 'green' type of agent in particular (H2b) have a positive effect on the level of the endogenous variables of the CEIS.

The influence of attitudes on innovation in general has been confirmed by Candel and Pennings (1999), among others, and on eco-innovation of firms in particular by Corral (2003). The relevance of ´green´ types of agents has been addressed mainly in management-oriented environmental research but without reference to eco-innovation (e.g. Aragón-Correa and Rubio-López, 2007; Buysse and Verbeke, 2003).

(ii) With regard to the relevant resources, the Carnegie-School points to specific traits and abilities such as risk taking, experimentation and creativity (see Section 4.3.2.2). The relevance of such behavioural elements for innovation in general has been confirmed by Beckenbach et al., (2012) with reference to the insights of creativity research (e.g. Amabile, 1997; Ames and Runco, 2005). In eco-innovation research, the relevance of specific capabilities is discussed in the context of applying the resource-based view of the firm to environmental firm behaviour (e.g. Hart, 1995; Kammerer, 2009). Furthermore, some authors see the implementation of environmental management systems as the expression of 'green capabilities' and observe a positive influence on eco-innovation (e.g. Kesidou and Demirel, 2012; Khanna, et al., 2009; Rennings et al., 2006). Additionally, past eco-innovative activities are considered important because those might imply that specific qualifications have been developed (Horbach 2008; Rehfeld et al., 2007). Hypothesis 3 (H3) captures these aspects:

H3. The degree of individual characteristics relevant for innovation in general (H3a), the particular resources available for environmental product innovations (H3b), and past eco-innovation behaviour (H3c) have a positive effect on the level of the endogenous variables of the CEIS.

Fig. 9: The CEIS model



The core structure is positioned in the centre. The latent variables on the right represent behavioural aspects related to environmental issues, and the latent variables on the left aspects related to innovation in general.

(iii) The findings of the European Union's Community Innovations Statistics give evidence for the role of constitutive 'hard' corporate goals as drivers of innovation in general. For the survey period 2006 to 2008, expansion of the product range was the most commonly mentioned goal, and the goals of increasing market share and costs reduction were mentioned less frequently (Eurostat, 2012). Among others, Porter and van der Linde (1985) have stated that eco-innovations might advance or meet the fulfilment of economic goals, for example, cost reduction. This was investigated in empirical eco-innovation research and cost reduction has been proven to be a relevant driver of eco-innovation (e.g. Belin et al., 2009; Frondel et al., 2008; Horbach et al., 2012). In the light of the above, Hypothesis 4 (H4) states the following:

H4. 'Hard' economic goals as drivers for innovation have a positive effect on the level of the endogenous variables of the CEIS.

(iv) The relevance of market forces and competition has been debated in the literature on innovation at least since Schumpeter and has been prominently advocated by Porter (1998). Boone (2000) and Vives (2008), among others, offer empirical evidence for the relevance of

such factors with respect to innovation in general. From a similar perspective, Horbach (2008) notes a positive correlation between eco-innovation and expected performance in terms of expected demand. Furthermore, the crisis in the automotive industry that prevailed at the time of the survey might be considered an 'external shock' as discussed by the Carnegie School (see Section 4.3.2.2). Thus far, few studies have been conducted about the effect of the crisis on innovation behaviour in general and no study has focused on eco-innovative behaviour in particular. As for the former, Filippetti and Archibugi (2011) find evidence that European firms are starting fewer new projects. This is taken into consideration in Hypothesis 5 (H5):

H5. Anticipated market conditions in general have an effect on the level of the endogenous variables of the CEIS (H5a). In particular, the crisis in the automobile industry influenced eco-innovative intentions in terms of article 4(1) ELVD (H5b).[80]

4.3.5. Data and methodology

The present study is based on a quantitative survey of firms belonging to the German passenger vehicle supply industry from 2009. Obtaining the address data was relatively labour-intensive because of unclear distinctions in the NACE-codes and the study's restricted focus on the passenger vehicle supply industry. Initially, publications and databases were analysed, and 2,400 suppliers were identified. Approximately 1,700 of these were contacted by telephone in order to establish whether they belonged to the target group as well as to find suitably qualified contacts.[81] The final address dataset to which the questionnaire was sent to comprised 1,319 suppliers; it can be assumed that the population was effectively covered.

The rate of return of usable answers was 21%. Of the responding firms, 56% could be classified as large-scale enterprises, 33% as medium-sized enterprises, and 10% as small and micro enterprises, according to the European Commission's system of classification by company size (European Commission, 2005). 66% of the companies stated that they belonged to the

[80] Part 5b of H5 is related solely to eco-innovation because this was directly focused on in the survey (see Section 7.2, Appendix A) and hence already covers a specific decision made by the companies.

[81] Corresponding information was available for the remaining approximately 700 companies in Automobil - Produktion (2007).

first tier in the value chain, 28% of companies were part of the 2nd tier, and only 6% of companies belonged to the 3rd tier.[82]

The statistical analysis was undertaken using the method of structural equation modelling (SEM) (see for an introduction Kline, 2011). SEM may be characterised briefly as a combination of multiple factor analyses (the 'outer model') and OLS regressions (the 'inner model' or 'path model') in which relations between multiple independent latent variables and one or more dependent latent variables can be calculated. The latent variables can simultaneously represent both dependent and independent variables. SEM thus allows the examination of more complex relationships than the usual regression methods and is a suitable method to analyse the CEIS with its three endogenous variables. Because the present empirical analysis is partly exploratory and not based on well-defined constructs and, further, because (multi)normal distribution is not met for all variables (which cannot be expected in this context, anyway), the specific SEM-method selected was the 'partial least square' or 'projection to latent structures' (PLS) approach developed by Wold (see for an introduction Wold (1980, 1974); see also Chin, 1998; Kock and Lynn, 2012).[83] The analysis follows the guidelines of the American Psychological Association's 'Statistical Task Force' (Wilkinson and Task Force on Statistical Inference, 1999) and refers to effect sizes.[84] Distinctions are thereby drawn between the direct effects and resulting effect sizes[85], on the one hand, and the total effects[86] and resulting effect sizes, on the other.

4.3.6. Empirical results

At the centre of the present study is the inner model by which the hypotheses formulated in Section 4.3.4 are tested. With regard to the outer model, it should only be pointed out here

[82] Multiple answers were permitted; companies were classified according the highest tier mentioned.

[83] The calculations were undertaken with the software programme WarpPLS by Ned Kock (2012) using PLS regression. Because WarpPLS is relatively new, the results were double-checked using Smart-PLS (Ringle et al., 2005).

[84] Effect sizes measure the relevance of an effect without reference to the level of significance. (Cohen, 1988).

[85] Cohen (1992) classifies effect sizes from 0.02 to below 0.15 as small; from 0.15 to below 0.35 as medium; and above 0.35 as large.

[86] Total effects are composed of the sum of the direct effects (path coefficients) and the indirect effects (via other related variables); the same applies to effect sizes (Cohen, 1988).

that the empirical test criteria (see Hair et al., 2012 for an introduction) all achieve satisfactory values, thus fully confirming the outer model (see Appendix 7.2, B1; Appendix 7.2, A shows an overview of the latent variables, the associated items and the corresponding questions in the questionnaire; mean values and standard deviations are also given).

The reporting and discussion of results in this section is structured as follows: (i) first, the degrees of explanation of the regressions and the results concerning H1 are given; second, with regard to the findings related to the variables influencing the CEIS, a distinction is drawn between aspects of behaviour that are related to (ii) eco-innovation in particular (H2b, H3b, H3c, H5b) and (iii) innovation in general (H2a, H3a, H4, H5a).[87]

It should be noted that the hypotheses were derived (in section 4.3.4) without making assumptions about possible differences concerning the influences of the exogenous variables on the single endogenous latent variables of the CEIS. As the following shows, there are differences, which have to be taken into account.

(i) The adjusted coefficients of determination ($R^2_{adj.}$[88]) reach relatively high levels with values of 0,26 (EcoGo-Ov), 0.42 (EcoGo-Reg) and 0.58 (EcoInnoInt-Reg) (see for this and the following Fig. 10 and Fig. 11 and Appendix 7.2, B2). As the three values of the cross-validated redundancy measure Q^2 of Stone (1974) and Geisser (1974)[89] are well above zero (see Appendix 7.2, B2), the predictive relevance of the regression models is confirmed. The results also confirm H1 about the chain of effects within the CEIS, because the variable EcoGo-Ov exerts a strong influence on EcoGo-Reg. The latter also has a strong influence on EcoInnoInt-Reg and EcoGo-Ov has no direct effect on EcoInnoInt-Reg but does have an indirect effect on EcoInnoInt-Reg via EcoGo-Reg. These results already provide evidence that the concept of

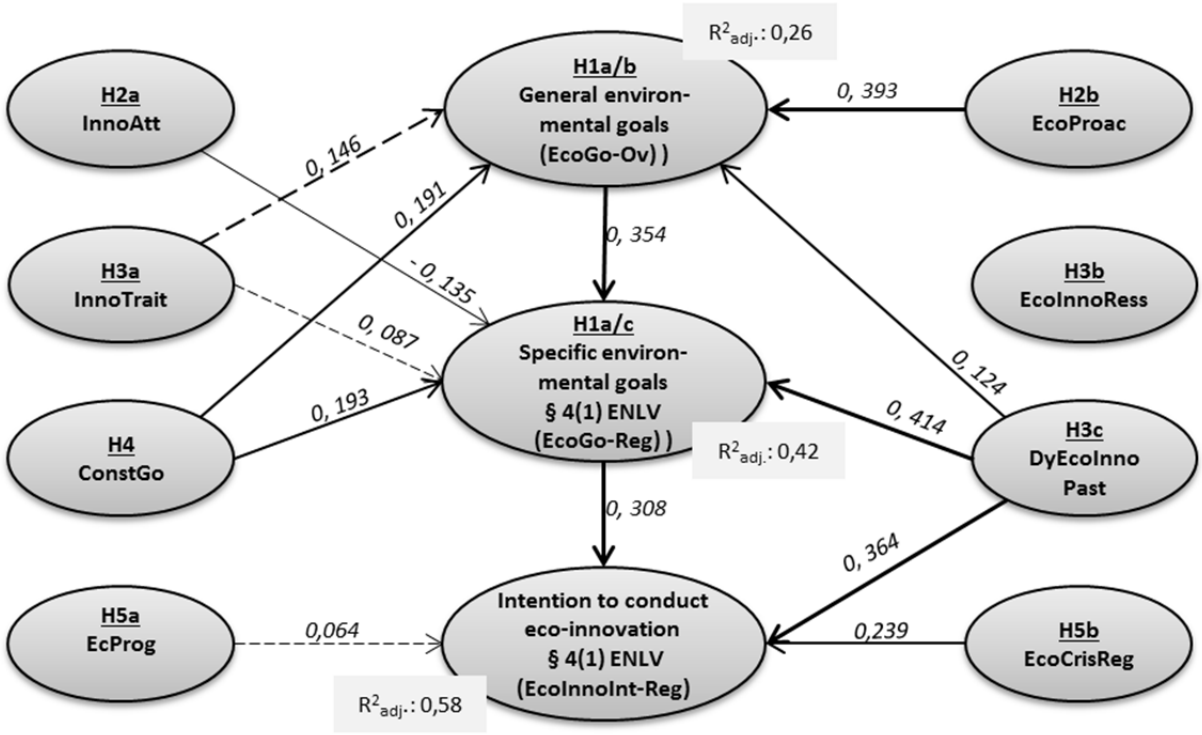
[87] Three control variables, the number of employees (size), the position on the supply chain (first tier or not (Dy1st tier)) and the influence of R&D, were calculated separately. For the first two, no significant effects could be found, while for the last, a significant negative path to EcoGo-Reg was detected. This, however, is not relevant in terms of effect size (see Appendices 7.2 A, B3). Thus, none of the three variables displays a relevant influence on the CEIS.

[88] For the calculation, Lord´s formular 1 was used, which is considered a suitable measure if the focus is on the replicability of the results (Leach and Henson, 2007).

[89] Q^2 is based on a blindfolding procedure and "represents a measure of how well-observed values are reconstructed by the model and its parameters" (Chin, 1998; see also Hair et al., 2012).

the CEIS is empirically meaningful and might be helpful in better understanding the decision-making processes leading to eco-innovation.

Fig. 10: The CEIS model – direct effects



The latent variables of the model (see Table A 1) are all shown but only the significant paths and the corresponding path coefficients are given. The dotted lines indicate significance at the 0.1 level (2-tailed) and the thickness of the arrows reflects the effect sizes, corresponding to Cohen's classification – thin: no relevant effect; medium: small effect size; thick: medium effect size (see Appendix 7.2, B2).

(ii) With reference to the relevance of the influence of the 'green' type of agent (H2b), only one significant path is to be observed, but this is a strong path with a considerable medium-sized direct effect from Eco-Proac to EcoGo-Ov. The values of the total effects show, though, that the ´green´ type has an indirect effect on EcoGo-Reg and EcoInnoInt-Reg via EcoGo-Ov. These findings are to be considered consistent, as the latent variable ´green´ type is directed to general environmental aspects and not to the requirements of article 4(1) ELVD. The influence, thus, is present, but becomes effective indirectly.

The findings regarding the relevance of the available financial and human resources that are specifically related to the requirements of article 4(1) ELVD (H3b,c) show that EcoInnoress

(H3b) has no significant effect at all (H3b is, therefore, not confirmed).[90] Thus, it can be assumed at least that deficits in resource endowment are not of relevance. Moreover, as the past eco-innovative activities, DyEcoInnoPast (H3c), show a significant path to each of the three endogenous variables, and the path coefficients to EcoGo-Reg and EcoInnoInt-Reg have the highest values and effect sizes in the inner model, the relevance of resource endowment (in the sense of Horbach (2008)) is verified.[91] It has to be noted that the direct effects to EcoGo-Reg and to EcoInnoInt-Reg are lower than the total effects – a result from the chain of effects within the CEIS. H5b can also be corroborated as the results show a significant and medium-sized path to EcoInnoInt-Reg. Obviously, the crisis in the automotive industry has led firms to pay increasing attention to the calls for improving the environmental performance and to comply in this regard with article 4(1) ENVD.

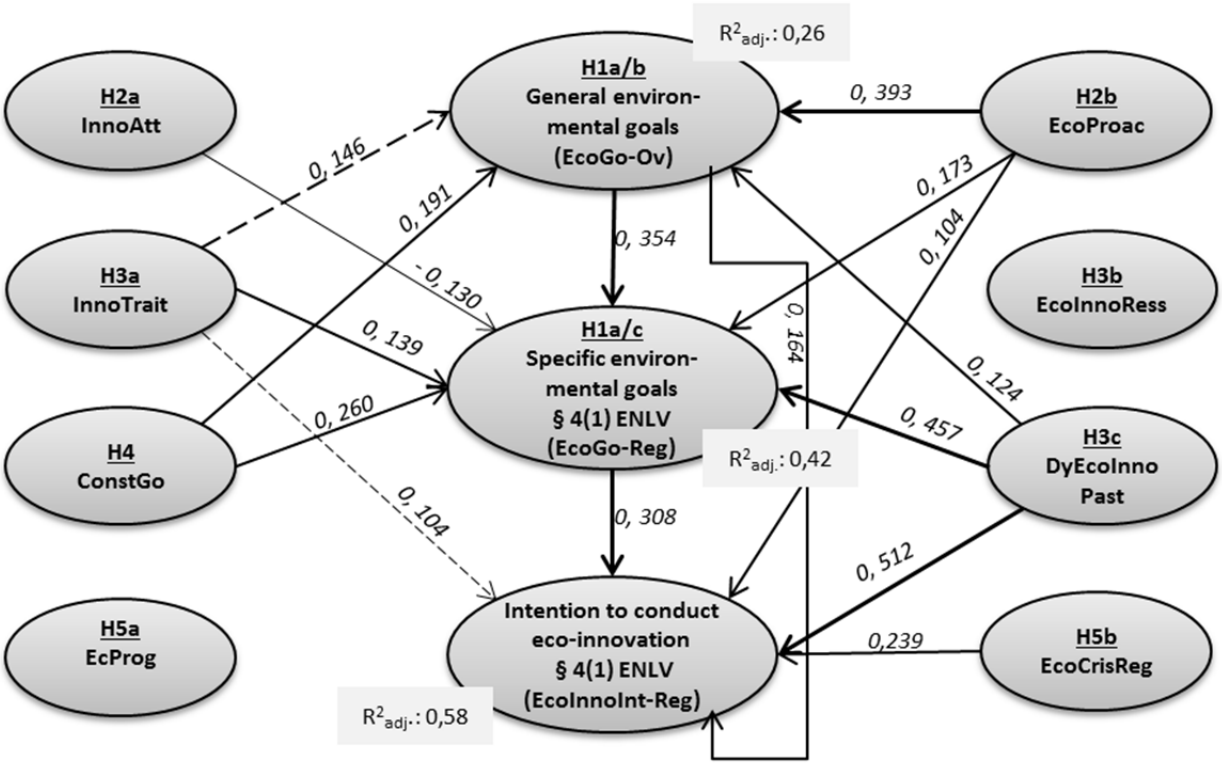
(iii) With regard to H2a, the statistics show only one direct, weak and negative influence from InnoAtt (H2a) to EcoGo-Reg and no influence to Eco-Go-Ov and EcoInnoInt-Reg. This is somewhat surprising because the items of the latent variable EcoInnoInt-Reg were collected in the questionnaire making explicit reference to general innovation activities (see Appendix 7.2, A). That an attitude towards innovation does not necessarily influence general goals concerning environmental aspects might be conceivable. Why, however, should a general attitude towards innovation not influence the extent of eco-innovation (positive or negative) at all and how might the negative influence to the specific goals be explained? This negative influence might be due to a preference toward ´normal´ innovations, but this then should be apparent in a negative path to EcoInoIn-Reg, too. A possible explanation of this puzzling result will be given below. For the time being it is to be noted that, concerning H3a, similar results occur, as InnoTrait (H3a) shows only two direct and relatively weak paths to EcoGo-Ov and EcoGo-Reg and no path to EcoInnoInt-Reg. The corresponding total effects are some-

[90] It was also tested whether the three types of resources influence the endogenous variables severally; this is not the case.

[91] These findings might also be interpreted as evidence for path dependency and/or for an ongoing, stable positive attitude towards the type of eco-innovation investigated in this study, and/or be an expression of the compliance to regulation.

what stronger and include the path to EcoInnoInt-Reg, but are still at a low level.[92] Hence, all in all, H3a can be confirmed, but only to a limited extent.

Fig. 11: The CEIS model – total effects



The latent variables of the model (see Appendix 7.2, B2) are all shown but only the significant paths and the corresponding path coefficients are given. The dotted lines indicate significance at the 0.1 level (2-tailed) and the thickness of the arrows reflects the effect sizes, corresponding to Cohen's classification – thin: no relevant effect; medium: small effect size; thick: medium effect size (see Appendix 7.2, B2).

As for H4, the statistics show that InnoConstGo has a direct effect on EcoGo-Ov and a direct and an indirect, stronger effect on EcoGo-Reg. It might be concluded that environmental goals are driven by hard economic goals and that there is a connection between the hard goals and the regulation under consideration. In this sense, these findings support the assumption of Porter and van der Linde (1985) as mentioned in Section 4.3.2. However, again, there is no significant path from InnoConstGo to EcoInnoInt-Reg. Thus, contradictorily, the specific type of eco-innovation investigated here is not connected with the hard economic goals (H4 is thus supported only partially). Finally, Hypothesis 5a, which addresses the ex-

[92] The model comprises a path from InnoTrait to InnoAtt .

pected performance of companies, can only be confirmed to a limited extent because there is no path to both of the latent variables concerning environmental goals. The direct path that leads from EcProg to EcoInnoInt-Reg is significant only at a 10% level and so weak that the total effect is not significant at all. In light of the findings concerning the relevance of the crisis in the automotive industry (see above), this seems contradictory, too (keeping in mind that the time frame of the endogenous latent variable Eco InnoIn-Reg covers five years).

To sum up, with regard to the results concerning those variables, which are not directly related to environmental matters, a mixed picture emerges and it becomes evident that these variables do not or rarely display an influence on the intention to conduct eco-innovation. However, three of those four latent variables are related to innovation in general and cover crucial aspects. The question is whether those variables do not only influence eco-innovation, but rather influence innovation in general, or whether those variables are generally not suitable for explaining innovation. To analyse this further, yet another structural equation model was calculated. The endogenous latent variable of this model comprised the intention to conduct innovation (in general) in the next five years (InnoInt; corresponding questions were part of the questionnaire; see Appendix 7.2, A) and the exogenous latent variables were those discussed above, namely those not directly related to environmental aspects. The results show that there is a significant influence with a (considerable) medium-sized total effect from InnoAtt to InnoInt, and significant, but smaller effects from InnoConstGo and EcProg (see Appendix 7.2, C). InnoInt has an $R^2_{adj.}$ of 0.23, and thus the conclusion that the variables under consideration are suitable for explaining innovation in general can be drawn. How, then, might the results concerning eco-innovation be explained? Insights from experimental behavioural economics research might offer an explanation: companies, or the relevant staff in companies, seem to undertake a type of 'mental accounting' (Thaler, 1999). They keep separate entries – cognitively (at least) and perhaps institutionally as well – for 'innovations in general' and 'specific eco-innovations'. This, however, implies that eco-innovation is not to be viewed as business as usual concerning innovation behaviour of firms.

4.3.7. Summary, implications for further research and policy design

The aim of this study was to contribute to further development of eco-innovation research from a behavioural point of view by applying the Carnegie School's Concept of Initiation model. The CEIS model was conceived for this purpose and related to the implementation of article 4(1) of the ELVD by the German passenger vehicle supply industry. The nucleus of the CEIS is composed of the following three endogenous variables: general environment-related objectives; regulation-specific objectives; and eco-innovative intentions. The CEIS and the related hypotheses cover relevant aspects of the decision-making process that lead to eco-innovation and incorporate both intra-company and external factors. Statistical method structural equation modelling was chosen because this allows for analysis of more complex interrelations than common regression methods.

The results give evidence of the fruitfulness of this approach, as they show that the concept of the CEIS is empirically meaningful and that taking behavioural aspects into consideration helps to explain eco-innovation, and hence to design proper policy instruments. Furthermore, the results showed an intriguing discorrelation between behavioural aspects concerning innovation in general and eco-innovation in particular. All in all, the results give evidence of the necessity to form and evaluate more complex models of eco-innovation than those usually given in the literature. The CEIS may, therefore, bring together various starting points and perspectives in eco-innovation research, allowing for further issue-based subjects to be taken into account, such as sectoral specificities or different types of eco-innovation as proposed by Kammerer (2009) and the OECD (2010).

With regard to further research, there are several aspects to be mentioned. A validation of the CEIS in subsequent empirical research as mentioned above would be certainly desirable. Also, the relevance of specific resource endowments might be investigated further, in order either to confirm or reject the present findings, which display no effect. In light of the explanatory power of the CEIS, it would be worthwhile to investigate behavioural aspects of the Carnegie School's Concept of Initiation model, which could not be pursued in this study (e.g., the level of aspiration). Moreover, further research could expand the CEIS and include the evaluation of mental accounting effects, as well as the analysis of the influence of other aspects discussed in behavioural economics (e.g., loss aversion). This would integrate the dis-

cussion about eco-innovation of firms into a broader discussion of behavioural aspects of environmental conduct in general.

As for the implications of the present findings for regulatory design, the first conclusion to be drawn is that measures targeting singular aspects cannot sufficiently take into account the complexity of decision-making processes regarding eco-innovation. Instead, environmental policy measures addressing several levels of the goal-setting and decision-making process might be more expedient. Hence, policy instruments should take behavioural aspects of eco-innovation, e.g. in fostering proactive conduct, into consideration in applying suitable strategies to overcome behavioural aspects such as mental accounting effects, and in strengthening environmental goals. With regard to the latter, the present findings indicate, in principal, that naming eco-innovative goals explicitly with respect to innovation in the framework of article 4(1) ELVD has led companies to establish goals and induced related eco-innovation, even though the regulation does not stipulate sanctions. This gives evidence for the relevance of the definition of clear goals in environmental regulation as discussed by Porter and van der Linde (1995).

4.4. A procedural model of trust dynamics and knowledge exchange in collaborative R&D (Artikel 4)

4.4.1. Introduction

Research on collaborative research and development (R&D) has expanded in the past two decades, and there seems to be a general understanding that trust is a necessary precondition for knowledge transfer between cooperation partners. This topic is discussed in different, often interconnected fields, such as innovation economics, organizational economics and management studies (e.g. Cooke, 1996; Tsai, 2001; Nooteboom, 2004; Asheim/Coenen, 2005; Inkpen/Tsang, 2005; Becerra et al., 2008; Balland et al., 2013).

However, despite these manifold discussions, the foundations of the behavioral dynamics of the interwoven process of trust and knowledge exchange occurring within collaborative R&D have rarely been investigated (but see Fritsch/Kauffeld-Monz, 2010; Beckenbach et al., 2012). This is somewhat surprising, as the literature has emphasized the dynamic nature of innovation processes and the necessity of a knowledge-based perspective (e.g. Nelson/Winter, 1982, Cohen/Levinthal, 1990). In particular, the literature about collective problem solving processes has focused on the stepwise character of such endeavors (e.g. Okada/Simon, 1997; Marengo/Dosi, 2005). Indeed, a dynamic perspective is essential for effective investigation of trust-based relationships, as trust is inherently related to experienced reciprocity (e.g. Gouldner, 1960; Güth et al., 2012).

Pursuing such a dynamic perspective immediately leads *first* to the question of which behavioral concept should be applied. This is not a trivial question, as there is no unified model of agency that is being applied in innovation economics or in organizational and management research (see also Nelson, 2012). Without doubt, however, the prevailing standard economic model is not appropriate in this regard, as the concept of the *homo oeconomicus* as a self-interested loner with unbounded cognitive capacities and knowledge does not conform to the time-consuming, precarious processes of trust and knowledge exchange as they occur in the real world.

An alternative to the standard economics approach is the concept of procedural rationality as developed by Herbert Simon (see for an introduction Simon 1997). Procedural rationality provides a dynamic perspective on innovation, as innovations are considered as (collective) problem solving processes with a corresponding focus on the knowledge dimension of innovation. That concept, at least with regard to the more familiar notion of bounded rationality, has long been acknowledged by researchers concerned with the topic of innovation (e.g. Nelson/Winter, 1982; Cohen/Levinthal, 1990; Dosi, 2004), yet its dynamic aspects have seldom been addressed.

One shortcoming of the concept of procedural rationality is its neglect of the issue of trust, although Herbert Simon's considerations about docility as a human trait provide a starting point for such a consideration (Simon 1990, 1991). This path Simon marked out can be pursued further by referring to the extensive literature about trust. Trust research, as indicated above, includes a dynamic perspective on the structure of trust based on interaction and traits. However, as Williamson (1985) points out, not all of the agents in the real word are trustworthy and behave accordingly; some are opportunistic. Thus, opportunism as the antithesis of trust and as a behavioral trait possibly hampering collaborative R&D also has to be accounted for.

The *second* question to be addressed is what method of analysis should be used. This question is also not easily answered. To inquire about dynamic behavioral aspects in a qualitative or even a quantitative survey, for example, makes huge demands on the memory and the perception of a respondent and therefore is prone to error (see also Fehr/Fischbacher, 2003). Moreover, as Nooteboom (2012) states, current statistical methods are inappropriate for analyzing complex interactive processes. Shortcomings are also apparent with regard to experimental research. Of course, there is a lot of experimental research giving evidence concerning trusting behavior (e.g. Berg et al., 1995; Gächter et al., 2004; Cox/Deck, 2005; Brülhart/Usunier, 2012). However, most of the experiments only apply to dyadic relationships and at least at the current state of the art, the application of experiments is limited with regard to multilateral interactions (see also Fehr/Fischbacher, 2003).

Against this background, it is worthwhile to make use of simulation models in the form of multi-agent systems. Such models are appropriate when evaluations of possible outcomes of dynamic and complex behavioral processes are of interest (see for an introduction Rails-

back/Grimm, 2012). Hence, with regard to the topic of the dynamics of a trust-based relationship, simulation models might offer insights about the "complex interaction [between] virtuous cycles of trust- building and vicious cycles of collapse" (Nooteboom, 2012, 40). There already exists a considerable amount of computer models that have been set up in different scientific disciplines in order to analyze trust as a behavioral element of interaction (see for an overview Castelfranchi/Falcone, 2010; Nooteboom, 2012; Balakrishnan/Majd, 2013). Relatively few models, however, are concerned with the interrelation of trust and knowledge exchange (e.g. Chli/de Wilde, 2008; Otto, 2012), or with collaborative R&D (e.g. Beckenbach et al., 2012), and none of these explicitly discuss the relational dynamics among the agents.

This study aims to make a contribution to the research about collaborative R&D by incorporating a behavioral point of view. This entails *first* developing a conceptual model, which *in a second step* is formalized and *in a third step* is transferred into a simulation model by using the programming environment Mathematica®. To this end, the concepts of procedural rationality and trust research are merged, taking into consideration the dynamic aspects as well as their precarious foundations and the heterogeneity of agents. Accordingly, the behavioral core elements are the knowledge dimension (Kd) and the trust dimension (Td), hence the model developed is referred to as the Kd-Td model.

The study is organized as follows: The theoretical foundations are given in Section 4.4.2, by referring to the concept of procedural rationality and to trust research. The Kd-Td model is presented in Section 4.4.3. Section 4.4.4 and 4.4.5 are concerned with the simulation model and the results. The study closes with a summary and a consideration of the implications for further research as well as for innovation policies aimed at promoting collaborative research and development, either at the level of the firm or through state support (Section 4.4.6).

4.4.2. Theoretical background

4.4.2.1. Bounded and procedural rationality

The concept of bounded rationality was developed by Herbert Simon with the specific goal of providing economists with a more realistic concept of agents than standard economics provides (see for this and following e.g. Simon 1986a, 1993, 1997, 1999). Bounded rationality refers to restrictions in human conduct, resulting from internal aspects (e.g. limitations to transform information into new knowledge, limited memory) and external aspects in the form of environmental conditions (e.g. education, availability of resources). This perspective on human conduct was extended by Simon by the concept of procedural rationality. Procedural rationality includes the limitative aspects of bounded rationality, but is furthermore concerned with the question of how bounded rational agents are capable of action, of making decisions and of innovating. Procedural rationality thereby always implies that agents are heterogeneous – with regard to their limitations, their abilities, their motivations and their goals.

One building block of procedural rationality which is relevant in the context of this study is the concept of problem solving (see for this and the following Newell/Simon, 1972; Simon 1986a, 1997; see for an introduction Beckenbach/Daskalakis, 2013). Problem solving considers innovation as a situation, where no well-known routines allow for the solution of a given problem or the achievement of a given objective. Briefly, problem solving can be described as a stepwise cognitive endeavor, which starts with the perception of a problem and ends either with a solution or the termination of the problem solving process. Given heterogeneity in terms of ability, resource endowment and knowledge, the advantages of a collaborative endeavor are evident: in the process of collective problem solving, relevant parts of a given problem might be allocated to different persons in one step according to their specific endowments and might be reintroduced in the form of new knowledge in the next step, contributing to the further steps and the solution of the problem at stake (e.g. Okada/Simon, 1997; Marengo et al., 2005; Beckenbach et al., 2012). To which extent this is successful depends on the amount and quality of the knowledge already gained, the amount and quality of the knowledge transferred and the procedural abilities of the agents, e.g. in the form of

their absorptive capacity[93].

4.4.2.2. Trust and behavioral traits

Herbert Simon argues that due to bounded rationality and heterogeneity, agents have to learn from other agents in order to acquire knowledge and skills (see for this and the following Simon 1990, 1991). Therefore, according to Simon, social evolution has led to a specific human attribute, docility. Docility is defined as a trait which "describes persons who are adept at social learning, who accept well the instruction society provides them" (Simon 1990, 1666). It fosters group cohesiveness and allows for interaction without fear of being exploited. Docility is part of the concept of procedural rationality, as it enables agents to act by broadening their own capacities through the interaction with others. This is an uncommon perspective on bounded or procedural rationality and to date has not received much discussion (but see Knudsen, 2003). Unfortunately, Simon did not develop the topic further and in particular did not apply it to the concept of collective problem solving. In order to fill this gap, it is worthwhile to refer to the broad field of trust research, which provides a theoretically and empirically based background for research of social interaction and thus can be appropriately applied to extend Simon's approach.

Trust is a research topic in several fields of social sciences. Correspondingly, manifold perspectives and definitions of trust are to be found (see for an introduction Castelfranchi/Falcone, 2010, Nooteboom, 2012). However, in a nutshell, a common denominator can be identified, namely that trust enables agents to rely on other agents without safeguarding against opportunistic behavior of the others (see for a more detailed discussion Daskalakis/Kauffeld-Monz, 2007). Trust thereby is seen as an individual trait, which is "updated on the basis of experience" (Nooteboom 2012, 41; see also Lewicki/Bunker, 1995). This obviously hints at the dynamic nature of trust, which is inalienably related to the topic of reciprocity.

Gouldner in his seminal discussion about reciprocity states that reciprocity can be characterized "as a mutually contingent exchange of benefits between two or more units." (Gouldner 1960, 164). This involves at least two sequential steps of interaction: **First**, one agent **A** deliv-

[93] Absorptive capacity refers to the ability of agents to interpret, categorise and adapt received knowledge (see Cohen/Levinthal 1990).

erers something to another agent **B**, who **second** "*reciprocates* **A**´s services" (ibid., 163). With regard to the second step, reciprocity implies "that **B**´s service to **A** is contingent upon **A**´s performance." (ibid.; see also e.g. Bolton et al. 2013; see for a more detailed discussion Daskalakis/Kauffeld-Monz, 2007). Reciprocal behavior from the point of **B** then involves at least two interdependent evaluations: one about the delivery of **A**, and the other about **B**'s own delivery in return and vice versa. If an interaction has more than two steps of exchange, it becomes more complicated: **A** also will evaluate the reciprocal behavior of **B** in the light of his own delivery in the exchange and then will adjust his return, **B** will... and so on, until the goal of the interaction is reached or the process is terminated. Selten calls this process the "measure of measure strategy" (Selten, 1998, 427) which is, however, limited by the bounded rationality of agents.

The dynamics of such a trust based interaction is determined by a set of behavioral traits that may be described as follows. With regard to the agents' own delivery it is determined by the individuals' propensities to trust and to behave reciprocally; and with regard to the delivery of the other agents by the sense of fairness and/or by the propensity to tolerate non-reciprocal behavior (see e.g. Axelrod, 1984; Cox/Deck, 2005; Fehr, 2009; Dubois et al., 2012). Moreover, in an application to the topic of knowledge transfer, Gächter et al. (2010) found, that the amount of knowledge transferred in a first time step from **A** to **B**, the "initial gift" (ibid., 895, referring to Berquist and Ljunberg, 2001) is crucial for the response of **B**.

Analyzing trust and reciprocity as behavioral traits of agents should not disguise the fact that agents are prone to opportunistic behavior, as Williamson (1981, 1993) has pointed out. Correspondingly, Fehr and Fischbacher (2003) state that cheating is a common human trait. There are some experiments in experimental economics dedicated to this topic. Fischbacher and Föllmi-Heusi (2013), for example, recently found that more than 20% of the participants of their respective experiment were lying with regard to their own benefit when given the opportunity (see also Utikal/Fischbacher, 2013). Hence, a further behavioral trait is of relevance, namely the propensity to act opportunistically. Agents however, even if boundedly rational, are aware of the possibility of being cheated (Fehr/Fischbacher, 2003) which may result in more cautious behavior even in the course of a trust-based relationship.

Taking heterogeneity of agents into consideration, the behavioral traits discussed above lead to a multitude of possible conduct by agents. Hence, in any cooperative undertaking, differ-

ent types of agents can typically be found. With regard to this, Fehr and Fischbacher (2003) discuss the relevance and the outcomes of different group compositions. Based on observations made in public good experiments, they state that agents who are characterized by a strong reciprocal attitude will expect the same sort of behavior in return, when starting a cooperation. These (overly optimistic) expectations will not be fulfilled if there are others who are behaving in an opportunistic manner, and as a result, cooperations will break down.

4.4.3. The Kd-Td-model: A model of the dynamics of collaborative R&D

The present section attempts to integrate the problem solving perspective and the trust perspective and to merge them into a procedural model of the behavioral dynamics of collaborative R&D. Thereby a differentiation is made between the ´knowledge dimension´ (Kd) of collaborative R&D which refers to problem solving perspective and the ´trust dimension´ (Td) of collaborative R&D which refers to the trust related behavioral traits.

In the light of the discussion in Section 2.1, collaborative R&D can be considered as a collective problem solving process. This process obviously implies heterogeneity and necessitates transfer of knowledge between the interacting agents. The first proposition takes this into consideration and is concerned with the ´knowledge dimension´ of collaborative R&D:

> **Proposition 1:** Because procedural rational agents are heterogeneous with regard to their cognitive capacities and their knowledge base, collaborative R&D as a collective problem solving process is a means to (partly) overcome the limitations of bounded rationality and to conduct innovation more successfully. The specific limitations and abilities of the agents involved (e.g. in terms of adaptive capacity) then determine the success of a collaborative endeavor.

In the sense of the findings of trust research as outlined in Section 2.2, collaborative R&D might be considered as a conditional relationship contingent on the interplay of behavioral traits related to trust. Proposition 2 takes this ´trust-dimension´ of collaborative R&D into account:

> **Proposition 2:** An ample propensity to trust and to behave reciprocally fosters the dynamics of the interaction of procedurally rational agents in collaborative R&D. By contrast, opportunistic behavior, a low propensity to tolerate non-reciprocal behavior and safeguarding against opportunism dampen the dynamics of collaborative R&D.

In terms of the ´measure of measure strategy´, the question is – what is the evaluative focal point (the object to be measured and to be transferred) in a R&D collaboration. From the point of view of collective problem solving, and taking into consideration the findings of Gächter et al. (2010, see Section 4.4.2.2), the answer is obvious:

> **Proposition 3:** Knowledge is the focal point of the evaluation process encompassing reciprocal behavior.

In the process of collaborative R&D, agents transfer knowledge from one to the other and in this process of mutual knowledge exchange (and the accumulation of new knowledge that accompanies this), an innovation might be realized. Taking the ´measure of measure policy´ into account, the stepwise character of this process shows:

> **Proposition 4:** Collaborative R&D is characterized by a stepwise process in which step by step, knowledge elements are transferred, the obtained knowledge is evaluated, the amount of knowledge to return is chosen and again further parts of knowledge are transferred. In this context, the amount of the ´initial gift´, the knowledge exchanged in the first time step of a cooperation, plays a crucial role.

Taking heterogeneity into account entails considering agents as heterogeneous not only with regard to their cognitive capacity but also with regard to their behavioral traits. The totality of the elements of the knowledge- and trust dimension and their respective values then mark every single cooperative endeavor, leading to a multitude of different possible group compositions. The concrete composition of a group thus shapes the outcome of the collaborative R&D. This leads to the next proposition:

> **Proposition 5:** The outcome of collaborative R&D depends on the group composition, namely the specific types of agents involved with regard to their knowledge-related traits on the one side and their trust-related traits on the other side.

Coming back to the goal dimension of a trust-based interaction, a characteristic feature of collaborative R&D has to be taken into consideration. Resources are limited and therefore,

such collective endeavors have a finite character.[94] This finite limit is reached either in case the innovation is completed or in case resources are exhausted. (Of course, agents may choose to start a new project with their partners; this, however, is not a focus of this study.) In this sense, proposition 6 is as follows:

> **Proposition 6:** Collaborative R&D is a finite process.

The finite character necessitates that another specific aspect of collaborative R&D be taken into account. Due to the intangible character of knowledge, to bounded rationality and to the behavioral traits related to the trust dimension possibly dampening the interaction: In one precarious time step which is ex ante not predictable but most probably will occur close to the completion of an innovation, one agent **A** might have gained enough knowledge to conduct the innovation alone. Because rationality is bounded, the other cooperation partners might not be aware of the success of **A** – and hence **A** is given the opportunity to cheat and to exploit the results (see also Daskalakis/Kauffeld-Monz, 2007; Kauffeld-Monz, 2010). This point of time is considered in the last proposition:

> **Proposition 7:** There is a ´window of opportunity for defection´ inherent in the process of collaborative R&D.

It is reasonable to assume that from this particular point of time onwards, the cooperating agents will behave more cautiously. To which degree the ´window of opportunity for defection´ hampers the conduct of the cooperation then depends, among other factors, on the individual propensities of the agents to behave more cautiously.

4.4.4. Design of the simulation model

4.4.4.1. The Kd-Td-models model's equations

The Kd-Td model consists of three agents cooperating with the aim of achieving an innovation (see Figure 12 for the process). Thereby an innovation is a specified amount of knowledge to be accumulated in the cooperation by at least one of the agents (k_{inno} =12.75). Two variables and two parameters of the Kd-Td model are related to the knowledge dimen-

[94] The finite character of collaborative R&D is one major reason of why the trust dimension in collaborative R&D is of most relevance: Given backward induction, agents would not engage in such endeavors.

sion (Proposition 1), one variable and four parameters to the trust dimension (Proposition 2; see Table 3 for an overview of the variables and parameters). The collaboration process ends when k_{inno} is reached or after 100 time steps if not enough knowledge is gained by any of the agents (Propositions 4, 6).

The Kd-Td-model is based on three difference equations. The first equation is concerned with the knowledge dimension: Each of the three agents A_i possesses a stock of knowledge ($k_i(t)$) and in each time step receives and gives parts of knowledge ($tk_i(t)$) from and to both of the other agents (Proposition 4).[95] Bounded rationality is incorporated by the parameters α_i and $decay_i$, the former reflecting absorptive capacity and the latter the degradation of knowledge (Proposition 1). The amount of the individual knowledge stock in $k_i(t+1)$ then depends on the stock of knowledge of the previous time step plus the amount of knowledge received, weighted by α_i, minus $decay_i$. Equation (1) exemplifies this for agent A_1:

$$k_1(t+1) = k_1(t) + \alpha_1 \left(tk_2(t) + tk_{23}(t)\right) - decay_1 \cdot k_1(t) \qquad [1]$$

($k_1(t) \geq 0$; $\alpha > 0$; $tk_1 \geq 0$; $decay_1 \geq 0$)

Tab. 3 Behavioral variables and parameters of the Kd-Td model

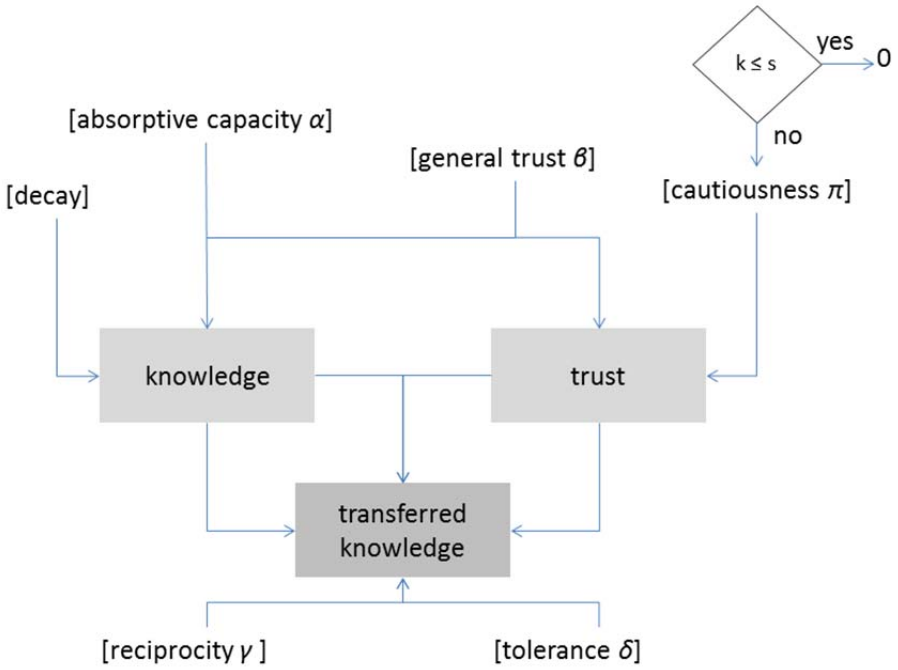
trust dimension		knowledge dimension	
variables			
tr_i	trust	k_i	knowledge
		tk_i	shared knowledge
parameters			
β_i	*general trust*		
γ_i	*reciprocitiy*	α_i	*absorptive capacity*
δ_i	*toleration of non-reciprocal behavior*	$decay_i$	*loss of knowledge*
π_i	*cautiosness*		

i= 1..3

Equation 2a,b is concerned with the changes and thus takes the trust dimension into account (Proposition 2). The amount of trust in each time step ($tr_i(t+1)$) is dependent on the interplay of three components. The *first* component is the amount of trust ($tr_i(t)$) of the pre

[95] It is assumed but not implemented in this model that in the given context receiving knowledge implies learning and generating new knowledge.

Fig. 12: Flowchart of the Kd-Td model



vious time step to which the product of the second and the third component is added. The *second* component thereby encapsulates the difference between the knowledge received (weighted by α_i) and the knowledge given (Propositions 3, 4); in addition, this difference is weighted by the individual propensities to trust β_i (Proposition 2). Thereby, two time steps are considered, allowing for a more process-oriented perspective. The *third* component takes the critical threshold *(s)*, the ´window of opportunity for defection´, into account (Proposition 7). Here, the parameter π_i represents the agents' cautiousness or sensitivity in case the completion of the innovation is in sight and the ´window of opportunity for defection´ opens. π_i is activated only in case *s* is exceeded, whereby *s* is expressed as a share of the amount of knowledge (k_{inno}) necessary for an innovation ($s = k_{(inno)} / 1{,}5$). Equation 2 exemplifies these for agent A_1:

$$\mathrm{tr}_1(\mathrm{t}+1) = \left[\mathrm{tr}_1(\mathrm{t}) + \beta_1 \left(\alpha_i \frac{\mathrm{tk}_2(\mathrm{t}-1)+\mathrm{tk}_2(\mathrm{t}\,0)+\mathrm{tk}_3(\mathrm{t}-1)+\mathrm{tk}_3(\mathrm{t}\,0)}{2}\right) - \frac{\mathrm{tk}_1(\mathrm{t}-1)+\mathrm{tk}_1(\mathrm{t}\,0)}{2}\right] - \frac{1}{1+c} \quad [2a]$$

$$c = \begin{cases} 0 \text{ if } \mathrm{k_i(t)} \leq s \\ \pi_i, \text{else} \end{cases} \quad [2b]$$

(π_1>0, β_1>0)

Equation (3) encompasses the ´measure of measure strategy´ (Proposition 3). Here, the

agents' propensities to behave reciprocally (γ_i, Proposition 2) and to tolerate non-reciprocal behavior (δ_i, Proposition 2) come into play. The amount of knowledge Tk_i transferred in *t+1* depends on whether the difference between the levels of trust t_i in *t* and *t-1* are positive or negative. In case the difference is positive, the product of the actual amount of trust and knowledge is weighted by γ_i. If the difference is negative, γ_i it is reduced by δ_i.

$$\mathrm{tk}_1(\mathrm{t}+1) = \begin{cases} \gamma_1 \cdot \delta_1 \text{ if } \mathrm{tr}_1(\mathrm{t}-1) > \mathrm{tr}_1(\mathrm{t}) \\ (\gamma_1 - \delta_1) \cdot \mathrm{k}_1(\mathrm{t}) \cdot \mathrm{tr}_1(\mathrm{t}), \text{else} \end{cases}$$

[3]

($\delta_1 > 0$, $\gamma_1 > 0$)

4.4.4.2. Types of agents, calibration and scenarios

In order to take heterogeneity into account (Proposition 5), three types of agents are defined (see Table 4):

- a default type (STANDARD), who conforms to the default setting,
- a more trusting type (TRUST), who displays a higher propensity for acting in a trusting manner and also has a higher initial amount of knowledge than STANDARD
- a more opportunistic type (OPPORTUNIST) with lesser respective values than STANDARD

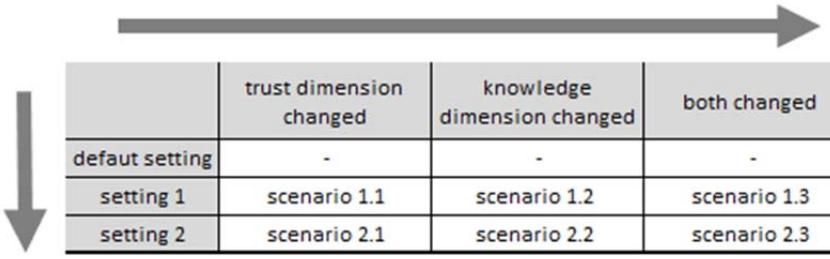
Two distinct settings of the values of the variables and parameters are defined in order to calibrate the model (setting 1, setting 2; see Table 4). In setting 1, the values of TRUST are initialized by the 1.15 fold and the values of OPPORTUNIST by the 0.85 fold of the values of the variables and parameters of STANDARD, except the values *of* δ_i, π_i and $decay_i$ which are adjusted inversely according to their conceptual content. In setting 2, the values are initialized by the 1.5 fold respectively 0.5 fold and δ_i, π_i and $decay_i$ again are adjusted inversely. Table 4 shows the values of the variables and parameters for all of the settings and assigns them to the knowledge and the trust dimensions accordingly.

Tab. 4: Behavioral variables and parameters for default setting, setting 1 and setting 2

	trust dimension						knowledge dimension					
variables	tr(t0)	tr(t0-1)					k(t0)	Δk (t0)	k(t0-1)	Δk(t0-1)		
parameters			*θ*	*γ*	*δ*	*π*					*α*	*decay*
default setting	2.5	2.5	3	0.006	0.002	0.01	3.5	0.2	3.5	0.2	0.85	0.1
setting 1 TRUST	2.875	2.875	3.45	0.0069	0.0017	0.0085	4.025	0.23	4.025	0.23	0.9775	0.085
setting 1 OPPORTUNIST	2.125	2.125	2.55	0.0051	0.0023	0.0115	2.975	0.17	2.975	0.17	0.7225	0.115
setting 2 TRUST	3.75	3.75	4.5	0.009	0.001	0.005	5.25	0.3	5.25	0.3	1.275	0.05
setting 2 OPPORTUNIST	1.25	1.25	1.5	0.003	0.003	0.015	1.75	0.1	1.75	0.1	0.425	0.15

Furthermore, Settings 1 and 2 each include three scenarios which differ with regard of the alteration of the values of knowledge and the trust dimension (see Table 5). In scenarios 1.1 and 2.1, just the values of the variables and the parameters of the trust dimension are changed according to the values given in Table 1 and the knowledge dimension remains at the default level. Inversely, in the scenarios 1.2 and 2.2, the knowledge dimension's values are altered, and the trust dimension remains at the default level. In scenarios 1.3 and 2.3 all of the values are changed respectively.

Tab. 5: Scenarios



	trust dimension changed	knowledge dimension changed	both changed
defaut setting	-	-	-
setting 1	scenario 1.1	scenario 1.2	scenario 1.3
setting 2	scenario 2.1	scenario 2.2	scenario 2.3

Altogether, this approach allows for comparing the results in two directions, as the arrows in Table 5 indicate: From the left to the right, within the two settings, the relative importance of the trust dimension, the knowledge dimension and their combinations can be evaluated. Downwards, between the two settings, the relative impacts resulting from increasing of the values can be analyzed. Thereby, in every scenario all of the possible combinations of heterogeneous group compositions are examined.[96] Hence, heterogeneity is taken into account by three types of agents, two different settings of values varying in terms of the multiple of the default setting and six scenarios.

4.4.4.3. Success indicators

In order to analyze the results of the Kd-Td model, six output indicators have been composed. These aim at capturing the possible efficiency of collaborative R&D with regard to time as well as to the knowledge and the trust dimension (see Table 6)[97]:

[96] The results of group compositions consisting solely of agents of the type TRUST or OPPORTUNIST are not considered here, but were analyzed beforehand. The results show, that the cooperations of three agents of the type TRUST always have the best performance, cooperations of three OPPORTUNISTs always fail.

[97] Note, that the success indicators related to *t(inno)* are only calculated for successful innovations.

- *t(inno),* which is the number of time-steps necessary for the accumulation of the relevant amount of knowledge.
- *KD*, which captures the difference between the stock of knowledge of each of the agents at the beginning (k_i (t0) and at the end of the cooperation (k_i (*tinno*).
- *KDT*, which relates *KD* to *t(inno)* and is a measure of the efficiency in terms knowledge acquisition.
- *TD*, which measures the difference between the initial amount of trust and the final amount of trust for each agent.
- *TDT,* which relates *TD* to *t(inno)* is a measure of the efficiency in terms of trust building.
- *OI*, the overall indicator. Here the product of *KD* and *TD* is divided by *t(inno)*. *OI* shows the overall balance of the cooperation.

Tab. 6: Success indicators

t(inno)	*KD*	*KDT*	*TD*	*TDT*	*OI*
$t(inno)_i$	$k_i(tend) - k_i(t0)$	$(k_i(tend) - k_i(t0))/t(inno)_i$	$tr_i(tend) - tr_i(t0)$	$(tr_i(tend) - tr_i(t0))/t(inno)_i$	$(k_i(tend) - k_i(t0))*(tr_i(tend) - tr_i(t0))/t(inno)_i$

t(inno) $_i$: Numbers of time step needed for k_{inno}
t(end) $_i$: End of the cooperation (either t(inno)i or at time step 100
k_i *(tend)* : Knowledge units at the end of the cooperation
tr_i *(tend):* Trust units at the end of the cooperation

The success indicators were calculated for each of the simulation runs. Additionally, for each scenario, the respective means and standard-deviations were also calculated. High means for *t(inno)* thereby indicate less successful group composition within a scenario, whereas higher values of the other indicators point to more success. High standard deviations point to larger differences within the groups of a scenario.

4.4.4.4. Structure of the simulation runs

In order to systematize the analysis, two strands of simulation runs have been conducted. The **first** one (Section 4.4.1) is concerned with the impacts of different values of parameters and variables. In order to evaluate those, heterogeneity is excluded and outcomes of collaborations of three agents of type STANDARD are explored. *Firstly*, the default setting is analyzed. S*econdly*, the impacts of the single alterations of the variables are taken into consideration by increasing them individually by the 1.15 fold and by the 1.5 fold of the default setting as well as decreasing them inversely. *Thirdly*, the same is applied with regard to the parameters (note the inverse coding of δ_i, π_i and $decay_i$). Additional simulation runs were con-

ducted altering all of the variables and parameters according to this schema.

The **second** strand of simulation runs (Section 4.4.2) is concerned with the impacts of heterogeneity. *Firstly*, the unsuccessful cooperations are discussed. *Secondly*, the successful cooperations are analyzed with regard to the two settings and six scenarios as presented in Section 4.1.2 as well as to level of the individual agents. The second strand closes *thirdly* with runs focused on variations of π_i and δ_i (the reason for this is given in Section 4.4.3).

At the end of the analyses of the first strand and at each of the ends of the different analyses of the second strand, an overview of the results is given.

4.4.5. Simulation results

4.4.5.1. Default setting and variation of the variables and parameters

4.4.5.1.1. Default setting

In the simulation run with the default setting three homogenous agents of the type STANDARD are cooperating. As Fig. 13 shows, trust is increasing slowly from 2.5 at the beginning of the cooperation to 34.00 at the end. The knowledge transfer between the agents drops in the second time step from 0.2 to 0.053, and only slowly increases until in the 47th time step the initial value is reached again (see Fig. 14). After that, knowledge sharing increases progressively. The accumulation of knowledge follows this pattern (see Fig. 15; see Fig. 16 for trust and knowledge combined in a phase space diagram) and at the beginning, agents actually lose knowledge as not enough knowledge is transferred to compensate for $decay_i$. The loss of knowledge is not regained until the 55th time step; after that, knowledge accumulates more rapidly. The critical threshold *s* is reached in time step 65, but does not affect the knowledge transfer in the subsequent time-step. The simulated cooperation ends with *t(inno)* amounting to 66. All of the agents are able to gain additional knowledge and trust within the cooperative endeavor, *KD* is 11.57 and *TD* is 31.58. The time related success indicators, *KDT*, *TDT* and *OI* have values of 0.18, 0.48 and 5.54 respectively (see also Table 7, reference value).

Fig. 13: Accumulation of trust*

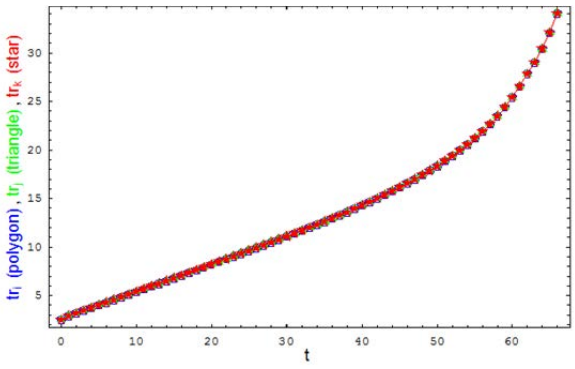


Fig. 14: Knowledge transfer

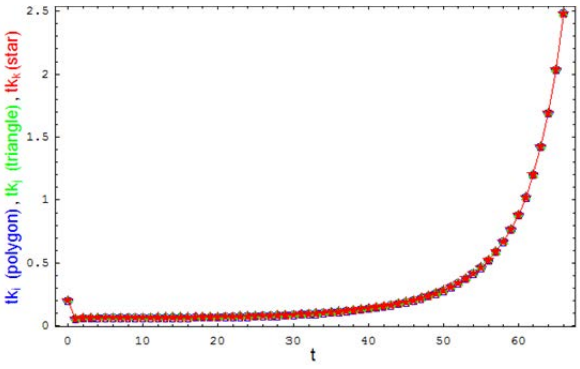


Fig. 15: Accumulation of knowledge

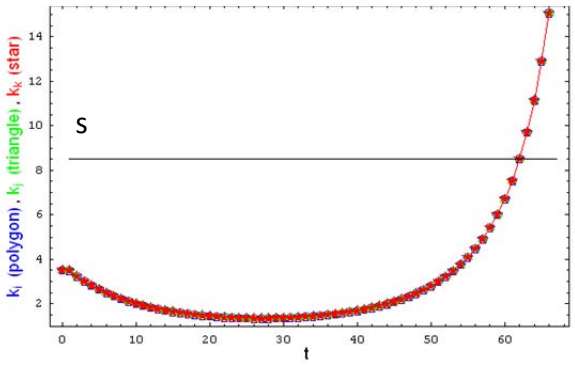
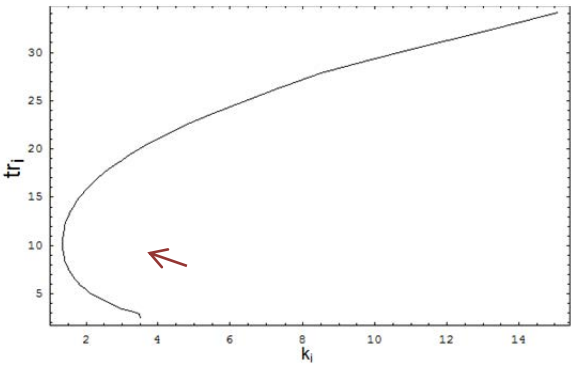


Fig. 16: Development of trust and knowledge A_i



*Note that as the agents are homogenous, the figures appear to include only one of the agents, but in fact contain the results for all of three agents.

4.4.5.1.2. Variation of the variables and the parameters

Variables

Not surprisingly, the time-steps necessary for gaining the relevant amount of knowledge are less than the time-steps of the default model, if the initial values of the variables are increased to 115% of the default values and even more, if increased to 150% (see Table 7). The fewest time-steps, 42, as well as the best values of all of the success indicators are performed, if the values of the variables are increased to 150% all together. The combined reduction of all the variables to 85% and 50% of the default values, correspondingly, increases the number of time-steps and leads to lower values of the success indicators. The decrease of all of the variables to 50% even causes the cooperations to fail; moreover, at the end of this cooperation the agents have less knowledge than at the beginning (hence *KD* has a negative value).

Regarding the variations of the variables in detail, the results show that the shortest time to

innovation, 50 time-steps, is realized by increasing tk_i to 150%; inversely, the decrease of tk_i to 50% induces the failure of the cooperation. The most knowledge and trust are gained when k_i is reduced to 50% (*KD:* 15.6 and *TD:* 35.4). With regard to *KDT*, *TDT* and *OI*, the success indicators relating *KD* and *TD* to *t(inno)*, the best performance is realized by setting tk_i to 150% (*KDT*: 0.26; *TDT*: 0.67; *OI*: 8.7).

Tab. 7: Results of the variable variations of the default setting - homogenous agents*

***t (inno)* (in % of the default setting)**

Reference value: 66

	+ 115%	-85%	+150%	-50%
k_i	95%	106%	86%	121%
tr_i	95%	106%	83%	123%
tk_i	91%	114%	76%	
All	82%	127%	64%	

***OI* (in % of the default setting)**

Reference value: 5.5

	+ 115%	-85%	+150%	-50%
k_i	104%	117%	114%	125%
tr_i	129%	97%	131%	98%
tk_i	123%	101%	157%	
All	120%	93%	111%	

***KD* (in % of the default setting)**

Reference value: 11.6

	+ 115%	-85%	+150%	-50%
k_i	99%	117%	98%	135%
tr_i	118%	100%	113%	109%
tk_i	108%	111%	112%	0%
All	100%	112%	82%	0%

***KDT* (in % of the default setting)**

Reference value: 0.18

	+ 115%	-85%	+150%	-50%
k_i	101%	107%	111%	108%
tr_i	120%	92%	132%	86%
tk_i	116%	95%	143%	
All	119%	86%	125%	

***TrD* (in % of the default setting)**

Reference value: 31.6

	+ 115%	-85%	+150%	-50%
k_i	100%	106%	101%	112%
tr_i	104%	103%	97%	111%
tk_i	104%	103%	107%	54%
All	99%	106%	87%	44%

***TrDT* (in % of the default setting)**

Reference value: 0.48

	+ 115%	-85%	+150%	-50%
k_i	104%	100%	116%	92%
tr_i	109%	97%	117%	90%
tk_i	114%	91%	140%	
All	120%	83%	136%	

*Free fields indicate the failure of the cooperation, the values of KD and TrD are given independently of the success

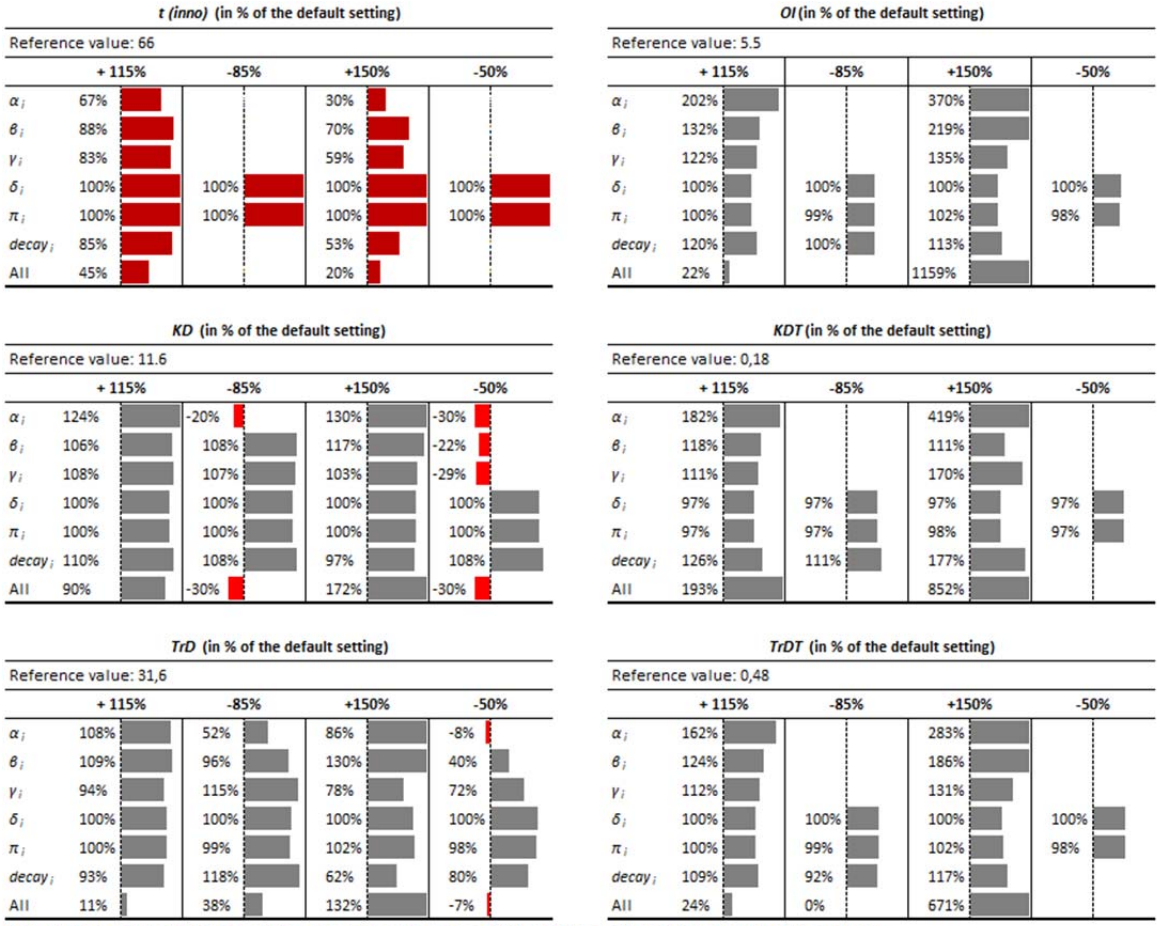
Parameters

Regarding variation of the parameters, the results point in the same direction, but are more pronounced (see Table 8). *t(inno)* decreases, the more the values of the parameters are increased; the shortest time to innovation, 13 time-steps, is realized in case all of the parameters are set to 150%. Factually, the values of all of the success indicators are the highest and exceed the default values by far, if all of the parameters are set to 150%. The decreasing to 85% and 50% leads to the failure of the cooperations. Thereby, again, agents actually lose knowledge.

Exceptions for both the increasing and the decreasing of the values are the runs where δ_i and π_i have been altered: δ_{ij} does not induce any changes in all of the results and π_i just

small changes, whereby $t(inno)_i$ and *OI* remain at the default level. Taking the other individual parameter variations into consideration, it is apparent that α_i, the parameter indicating absorptive capacity, has the greatest influence on the values of the success indicators and $decay_i$, the parameter indicating loss of knowledge, the second greatest influence. This applies for both the increasing and the decreasing of the values.

Tab. 8: Results of the parameter variations of the default setting - homogenous agents*



*Free fields indicate the failure of the cooperation, the values of KD and TrD are given independently of the success

To summarize: The simulation run of the default model shows a moderate cooperation, taking some time until a slow gaining of knowledge and trust occurs. The variations of the variables then give another picture and demonstrate that the initial amount of knowledge transfer (tk_i), ´the initial gift´ is of relevance for the success of knowledge sharing, as Gächter et al. (2010) have depicted. The best and also the worst results, however, are achieved if all of the variables are increased.

The results of the parameter variation are more heterogeneous than the results of the variable variations and differ considerably from the default setting. It is apparent that absorptive

capacity (α_i) and the decay of knowledge ($decay_i$) are the most influential parameters, but again, the alterations of all of the variables have the most pronounced effects. The propensity to tolerate non-reciprocal behavior and the critical threshold are only of minor relevance in the present parameter settings (but see Section 4.4.2.2.4).

All in all, the simulation runs reveal that the knowledge dimension is a necessary basis, but only when combined with the trust dimension can the best results be gained. Unsuccessful cooperations might lead to a loss of knowledge in absolute values, but also might end with a relative gain in knowledge and/or trust.

4.4.5.2. Setting 1 and 2: Taking heterogeneity into consideration

4.4.5.2.1. Failure of the cooperations with heterogeneous agents

For setting 1 the results show that within scenario 1.1, in which the three types of agents have different values regarding the trust dimension but identical default values for the knowledge dimension, all of the cooperations succeed. In scenario 1.2, however, where the knowledge dimension varies and the trust dimension remains at the default level, one cooperation fails. In scenario 1.3 where both the trust and knowledge dimension are changed, three interactions fail. Those three also are unsuccessful in all of the three scenarios of setting 2. Altogether, about 31 % of the cooperations fail.

What is the reason for this failure? One common denominator is the participation of the OPPORTUNIST (see Table 9). Besides scenarios 1.1 and 1.2, the only cooperation with the OPPORTUNIST in each scenario which does not fail is the one between two agents of type TRUST and one OPPORTUNIST. The following figures (17 - 22) show the simulation run for the cooperation between two OPPORTUNIST agents and one TRUST agent in scenario 2.3. As can be seen, the amount of trust the TRUST agent initially has decreases rapidly. From the 20th time-step on, it even switches over to distrust, taking on negative values. The knowledge transfer from TRUST correspondingly decreases rapidly, but does not dissolve completely[98] which is due to the increasing trust of the OPPORTUNIST. At the end of the failed cooperation, both agents have lost knowledge. However, not all of the unsuccessful cooperations result in a loss of knowledge. Moreover, apart from two cooperations in setting 2.3, in all of

[98] The values of tk_i always are above zero.

the failed cooperations the agents gain trust, some of them substantially.

To summarize: When opportunistic behavior occurs, cooperations are prone to failure. But cooperations with less pronounced agent types might succeed, in spite of OPPORTUNISTs. Moreover, strong counterparts, such as the TRUST agent, equipped with a higher amount of knowledge and trust can compensate for opportunistic behavior, at least as long as the OPPORTUNISTs are not in the majority. But, maybe, the OPPORTUNIST should not solely be blamed for the failure. The results of the exemplary simulation run of scenario 2.3 points to a phenomenon Fehr and Fischbacher (2003, see Section 4.4.2.2) discussed with regard to

Fig. 17: Accumulation of trust

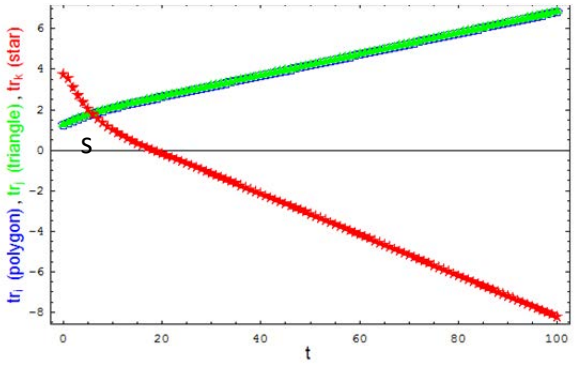


Fig. 18: Knowledge transfer

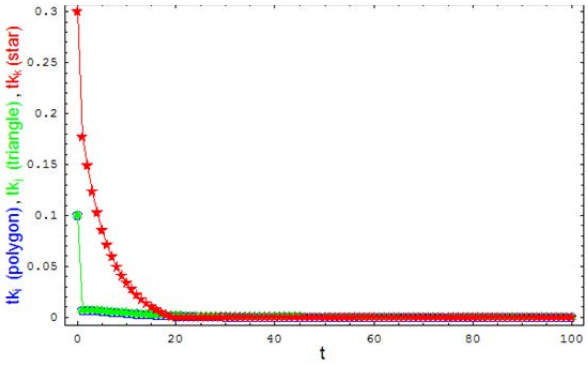


Fig. 19: Accumulation of knowledge

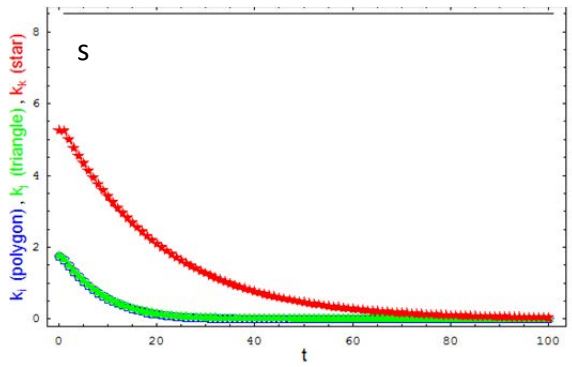


Fig. 20: Development of trust and knowledge *OPPORTUNIST*

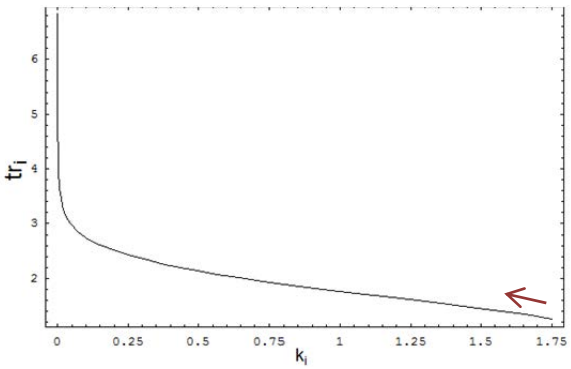


Fig. 21: Development of trust and knowledge *OPPORTUNIST*

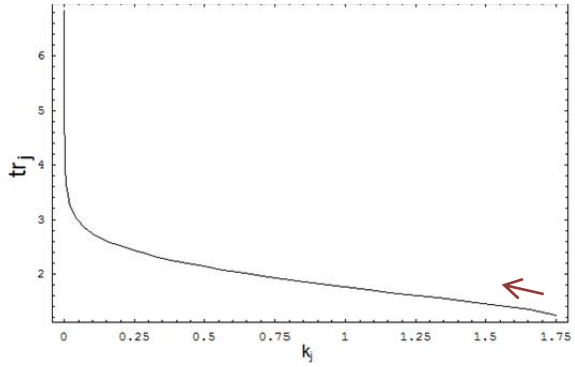
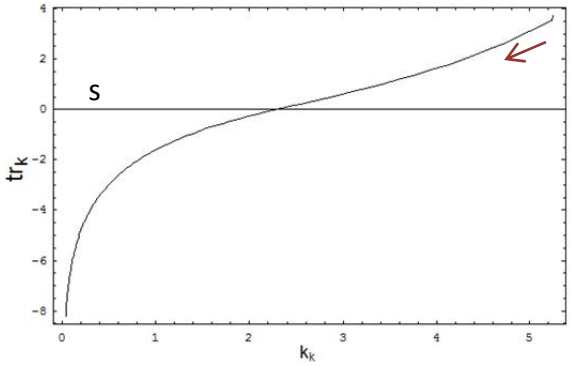


Fig. 22: Development of trust and knowledge *TRUST*



group composition and overexciting behavior: In the simulation, the strong agent type TRUST has made high demands of the cooperation partner at the beginning, which ultimately might have led to the failure of the cooperation. As, however, the cooperation between two types of STANDARD and TRUST within the same scenario is successful, it can be concluded that success and failure are determined by an intricate interplay of behavioral traits. From this point of view, cooperations with *first* a more homogenous population and *second* less differentiated behavioral parameters and variables seem to be more promising with regard to the overall possibility of success.

4.4.5.2.2. Results for successful cooperations of heterogeneous agents

Indicator t(inno)

The results of the simulations runs show that the means decline within the settings 1 and 2 respectively, as well as between the corresponding scenarios of settings 1 and 2 (see Table 10). Hence, the shortest time to innovation on the average is found in scenario 2.3. Concerning the standard deviations, a mixed picture emerges. Within setting 1, scenario 1.2 has the highest standard deviation, whereas within setting 2, scenario 2.3 has the highest values.

With regard to the level of the agents, the lowest time span, 12 time steps, is realized by two TRUST and one STANDARD in scenario 2.3., which is only about 18% of the result of the default setting (see Table 9). The most time steps, 92, are needed by the cooperation between two OPPORTUNISTs and one TRUST in scenario 1.2, followed immediately in the same scenario by the cooperation between two STANDARD and one OPPORTUNIST. In fact, all the cooperations in which the OPPORTUNIST participates have a longer duration compared to the respective group compositions of both of the other types of agents.

To summarize: Higher values of the trust dimension on the average lead to longer durations of the cooperations than higher values of the knowledge dimension. The higher both the values of the trust and of the knowledge dimension, the better are the results for *t(inno)* on average. Heterogeneity thereby pushes the cooperation processes. The involvement of the OPPORTUNIST leads to a longer duration of the cooperation process.

Tab. 9: Results of the parameter variations of the default setting - heterogeneous agents*

scenario 1.1

agent type	n	t (inno)	KD	KDT	TrD	TrDT	OI
STANDARD	2	77	12.6	0.2	33.2	0.4	5.4
OPPORTUNIST	1		13.6	0.2	33.6	0.4	5.9
STANDARD	2	58	11.5	0.2	31.1	0.5	6.2
TRUST	1		10.8	0.2	30.3	0.5	5.6
OPPORTUNIST	2	89	12.0	0.1	33.3	0.4	4.5
STANDARD	1		11.1	0.1	32.9	0.4	4.1
OPPORTUNIST	2	78	12.6	0.2	33.0	0.4	5.3
TRUST	1		11.0	0.1	31.5	0.4	4.4
TRUST	2	52	13.7	0.3	32.4	0.6	8.5
STANDARD	1		12.9	0.2	32.3	0.6	8.0
TRUST	2	59	11.0	0.2	30.5	0.5	5.7
OPPORTUNIST	1		12.6	0.2	31.4	0.5	6.7
STANDARD	1	67	11.4	0.2	31.6	0.5	5.4
OPPORTUNIST	1		12.2	0.2	31.8	0.5	5.8
TRUST	1		10.7	0.2	30.7	0.5	4.9

scenario 1.2

agent type	n	t (inno)	KD	KDT	TrD	TrDT	OI
STANDARD	2	91	12.0	0.1	32.3	0.4	4.3
OPPORTUNIST	1		10.2	0.1	33.1	0.4	3.7
STANDARD	2	50	9.3	0.2	29.2	0.6	5.5
TRUST	1		10.9	0.2	28.1	0.6	6.1
OPPORTUNIST	2		-2.2		17.2		
STANDARD	1		1.0		18.3		
OPPORTUNIST	2	92	8.8	0.1	31.9	0.3	3.0
TRUST	1		12.1	0.1	29.3	0.3	3.9
TRUST	2	36	11.4	0.3	27.9	0.8	8.8
STANDARD	1		9.8	0.3	28.6	0.8	7.8
TRUST	2	40	11.6	0.3	28.2	0.7	8.2
OPPORTUNIST	1		9.1	0.2	29.0	0.7	6.6
STANDARD	1	58	10.6	0.2	30.1	0.5	5.5
OPPORTUNIST	1		9.0	0.2	29.5	0.5	4.6
TRUST	1		11.6	0.2	28.4	0.5	5.7

scenario 1.3

agent type	n	t (inno)	KD	KDT	TrD	TrDT	OI
STANDARD	2		3.7		26.1		
OPPORTUNIST	1		3.5		26.6		
STANDARD	2	45	11.1	0.2	30.2	0.7	7.4
TRUST	1		12.0	0.3	28.7	0.6	7.7
OPPORTUNIST	2		-2.9		13.7		
STANDARD	1		-3.4		13.8		
OPPORTUNIST	2		1.5		24.2		
TRUST	1		1.6		21.2		
TRUST	2	33	12.5	0.4	29.2	0.9	11.0
STANDARD	1		11.5	0.3	29.9	0.9	10.4
TRUST	2	45	12.2	0.3	28.6	0.6	7.8
OPPORTUNIST	1		10.2	0.2	30.5	0.7	6.9
STANDARD	1	67	11.9	0.2	31.8	0.5	5.7
OPPORTUNIST	1		10.9	0.2	33.2	0.5	5.4
TRUST	1		13.1	0.2	29.4	0.4	5.7

scenario 2.1

agent type	n	t (inno)	KD	KDT	TrD	TrDT	OI
STANDARD	2		-0.9		23.6		
OPPORTUNIST	1		0.1		17.6		
STANDARD	2	46	12.8	0.3	31.3	0.7	8.7
TRUST	1		10.9	0.2	28.2	0.6	6.7
OPPORTUNIST	2		-3.4		11.5		
STANDARD	1		-3.5		20.3		
OPPORTUNIST	2		-2.7		13.8		
TRUST	1		-3.1		25.8		
TRUST	2	33	11.7	0.4	29.1	0.9	10.3
STANDARD	1		13.7	0.4	31.0	0.9	12.9
TRUST	2	48	7.4	0.2	23.1	0.5	3.6
OPPORTUNIST	1		11.8	0.2	25.4	0.5	6.2
STANDARD	1	72	8.2	0.1	28.6	0.4	3.3
OPPORTUNIST	1		11.3	0.2	27.9	0.4	4.4
TRUST	1		6.9	0.1	23.9	0.3	2.3

scenario 2.2

agent type	n	t (inno)	KD	KDT	TrD	TrDT	OI
STANDARD	2		-2.5		21.9		
OPPORTUNIST	1		-0.7		13.9		
STANDARD	2	38	9.8	0.3	27.0	0.7	7.0
TRUST	1		9.7	0.3	19.7	0.5	5.1
OPPORTUNIST	2		-1.7		10.1		
STANDARD	1		-2.5		22.4		
OPPORTUNIST	2		-0.5		15.6		
TRUST	1		-4.1		18.0		
TRUST	2	26	12.1	0.5	22.9	0.9	10.7
STANDARD	1		12.5	0.5	28.4	1.1	13.7
TRUST	2	37	9.8	0.3	16.8	0.5	4.5
OPPORTUNIST	1		11.5	0.3	23.6	0.6	7.3
STANDARD	1	65	9.5	0.1	28.0	0.4	4.1
OPPORTUNIST	1		11.8	0.2	28.6	0.4	5.2
TRUST	1		10.3	0.2	17.3	0.3	2.7

scenario 2.3

agent type	n	t (inno)	KD	KDT	TrD	TrDT	OI
STANDARD	2		-3.5	0.0	8.3		
OPPORTUNIST	1		-1.7	0.0	5.9		
STANDARD	2	23	7.7	0.3	24.0	1.0	8.0
TRUST	1		10.2	0.4	19.0	0.8	8.4
OPPORTUNIST	2		-1.8		2.2		
STANDARD	1		-3.5		-2.5		
OPPORTUNIST	2		-1.8		5.6		
TRUST	1		-5.3		-12.0		
TRUST	2	12	10.7	0.9	23.4	2.0	20.9
STANDARD	1		8.5	0.7	22.2	1.8	15.7
TRUST	2	18	9.8	0.5	17.5	1.0	9.5
OPPORTUNIST	1		4.0	0.2	9.4	0.5	2.1
STANDARD	1	72	5.7	0.1	26.2	0.4	2.1
OPPORTUNIST	1		3.7	0.1	18.3	0.3	0.9
TRUST	1		9.4	0.1	12.5	0.2	1.6

*Free fields indicate the failure of the cooperation, the values of KD and TrD are given independently of the success

Indicators KD and TD

Concerning *KD,* the amount of knowledge gained during the cooperation, a mixed picture emerges. For setting one, scenario 1 has the highest mean, followed by scenarios 1.3 and 1.2 (see Table 10). Thereby, the latter has the highest standard deviation. For setting two, the highest mean is realized by the groups of scenario 2.2, the lowest by scenario 2.3, which also has the highest standard deviation in both settings. With regard to the differences between the corresponding scenarios of both settings, except the pair 1.2 and 2.2, the values of setting 1 are higher.

Tab. 10: Descriptive statistics for *t(inno), KD, TD, KDT, TDT* and *OI* *

n			mean	standard deviation		mean	standard deviation		mean	standard deviation
21	scenario 1.1	*t(inno)*	68.57	13	*KD*	12.06	0.96	*TD*	32.06	1.09
18	scenario 1.2	*t(inno)*	61.17	23	*KD*	10.52	1.23	*TD*	29.74	1.75
12	scenario 1.3	*t(inno)*	47.50	13	*KD*	11.77	0.82	*TD*	29.96	1.38
12	scenario 2.1	*t(inno)*	49.75	15	*KD*	10.54	2.42	*TD*	27.67	3.05
12	scenario 2.2	*t(inno)*	41.50	15	*KD*	10.74	1.16	*TD*	23.25	4.64
12	scenario 2.3	*t(inno)*	31.25	25	*KD*	8.15	2.48	*TD*	19.78	5.08
21	scenario 1.1	*KDT*	0.18	0.04	*TDT*	0.48	0.08	*OI*	5.82	1.24
18	scenario 1.2	*KDT*	0.20	0.08	*TDT*	0.55	0.17	*OI*	5.74	1.94
12	scenario 1.3	*KDT*	0.27	0.07	*TDT*	0.67	0.16	*OI*	7.86	1.99
12	scenario 2.1	*KDT*	0.24	0.10	*TDT*	0.61	0.21	*OI*	6.74	3.42
12	scenario 2.2	*KDT*	0.30	0.12	*TDT*	0.62	0.24	*OI*	6.86	3.28
12	scenario 2.3	*KDT*	0.43	0.29	*TDT*	0.99	0.64	*OI*	7.13	7.31

*The values were calculated only for the successful cooperations

Thus, with regard to *KD*, the knowledge and the trust dimension have different impacts at the level of the settings and increasing of the knowledge dimension has a different effect than increasing of the trust dimension. These results might be related to both of the phenomena Gächter et al. (2010) and Fehr and Fischbacher (2003) described as well as to the ´measure for measure policy´ of Selten (1998). In both cases, the initial amount of knowledge, the ´initial gift´ is higher than in the scenario with the trust dimension, but trust is at the default level. In setting 1.2, the agents' knowledge dimension is lower than in setting 2.1. Thus, in setting 1.2 the ´initial gift´ is lower than in 2.2 and as a result, the cooperation partners exchange less knowledge.[99] The higher value of scenario 2.2 within setting 2 then might be explained by the phenomenon of ´overoptimism´. As in 2.2 the trust dimension is

[99] This shows, for example, if the process of the cooperation between two STANDARD agents and one OPPORTUNIST is analyzed. The initial amount of knowledge transfer drops after the first time-step from 0.2 to 0.052 for the two STANDARD agents and from 0.17 to 0.045 for the OPPORTUNIST. It then takes until the 71st time step, until the loss is regained and only in the 91st time step, does the cooperation succeed.

lower than in 2.1 and 2.3, the agents in 2.2 do not make as much demand on the reciprocal behavior of their partners as in scenarios 2.1 and 2.3 and therefore the knowledge transfer is smoother.

Regarding the level of the agents, the highest amount of knowledge is gained by STANDARD in cooperation with two agents of the type TRUST in scenario 2.1 - the value amounts to 13.74, which is about 20% higher than value of the default setting (11.58). The lowest amount (3.73) is gained by the OPPORTUNIST in the cooperation with both of the other types of agents in scenario 2.3 (see Table 9). Here, obviously, the lower values of the trust dimension are at work.

The results for *TD* are similar to the results for *KD*, with the exception that the mean for scenario 2.2 is not the lowest in setting 2 and likewise the standard deviation is not the highest (see Table 10). On the average, the most trust is gained in scenario 1.1 and the lowest amount of trust is realized in scenario 2.3. Correspondingly, the highest values of *TD* , 33.6, is found with one OPPORTUNIST in cooperation with two STANDARD in scenario 1.1, whereby the latter also gains a considerable amount of trust (33.2; both values are close to the default value (31.6); see Table 9). The lowest value of trust, 9.4, is realized by one OPPORTUNIST in cooperation two agents of the type TRUST in scenario 2.3.

To summarize: The amount of knowledge and trust gained on the average is higher if the cooperation partners are not too heterogeneous. Thereby, the results point to the relevance of a well-balanced relationship between the knowledge dimension and the trust dimension. Especially if the knowledge dimension is not met with an adequate trust dimension, the response to the ´initial gift´ might not be appropriate and the ´measure of measure strategy´ in terms of Selten (1998) will lead to a decline in reciprocal behavior. The results show further, that in group compositions with moderately heterogeneous agents, the OPPORTUNIST might be the one realizing the most knowledge gain in the course of a cooperation.

Indicators KDT, TDT and OI

The success indicators *KDT* and *TDT* relate the amount of knowledge and trust gained during the cooperation to the number of time-steps needed for the innovation. The results here show different and more regular patterns than those for *KD* and *TD* (see Table 10): The means are increasing within setting 1 from 1.1 to 1.3 and within setting 2 accordingly, also

the values of setting 2 are higher than those of setting 1. The values of the standard deviations follow this pattern, save for scenario 1.2, in which the values are slightly higher.

The best individual performance of *KDT*, 0.89, which is the fivefold of the default value, is realized in scenario 2.3 by two agents of the type TRUST in cooperation with one STANDARD (who gains the second highest value, 0.71; see Table 9). The lowest value of 0.05 is again realized in scenario 2.3 by one OPPORTUNIST in cooperation with both other types of agents. The highest level of *TDT,* 2.0, which is the fourfold of the default value, is found with two agents of the type TRUST in cooperation with one STANDARD in scenario 2.3, and the lowest value, 0.2, is realized by TRUST in cooperation with both other agent types , also scenario 2.3.

OI, the remaining indicator, combines the results in terms of knowledge, trust and time. Here, too, the mean values increase in the settings 1 and 2 and between the corresponding scenarios, except for the pair 1.2 and 2.2 (which is due to the value of KD, see Section 4.4.2.2.2; see Table 10). The values of the standard deviation again follow this pattern, with the one exception of scenario 2.2. The highest *OI*, 20.9, at the individual level is realized by two agents of the type TRUST in cooperation with one STANDARD in scenario 2.3 – this *OI* is 377% of the value of the default setting (see Table 9). The lowest value of 0.9 again is found in the OPPORTUNIST in the cooperation with both other agent types (scenario 2.3).

To summarize: If time to innovation is taken into consideration and the knowledge and the trust gained are also of relevance, then heterogeneity pays – at least as long as the cooperation partners are strong enough to successfully deal with opportunism.

4.4.5.3. Analysing discontinuities

As the analysis in Section 4.4.1 has shown, π_i and δ_i do not have a significant impact in the given setting of the values. Therefore, additional simulation runs were conducted whereby π_i and δ_i were increased, first in steps of 0.1 and then in steps of 0.5 until an effect emerged (results of the runs are given in Appendix 7.3). In order to do so, three types of cooperation were chosen, the default setting, the cooperation of the different types of agents in setting 1, scenario 1.1 as a moderate model of heterogeneity and the cooperation of the different types of agents in setting 2, scenario 2.3 as a model with more heterogeneity.

Fig. 23: Accumulation of trust

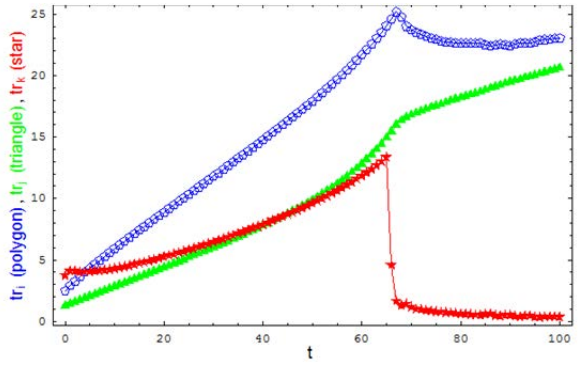


Fig. 24: Knowledge transfer

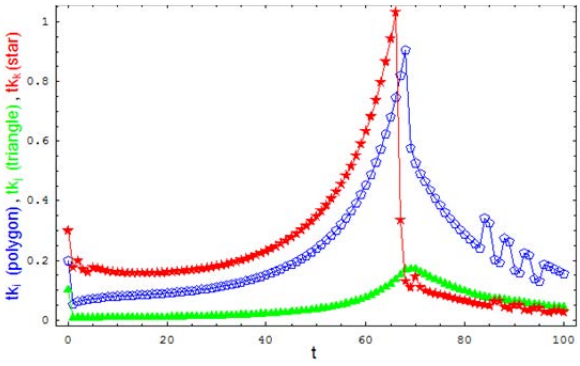


Fig. 25: Accumulation of knowledge

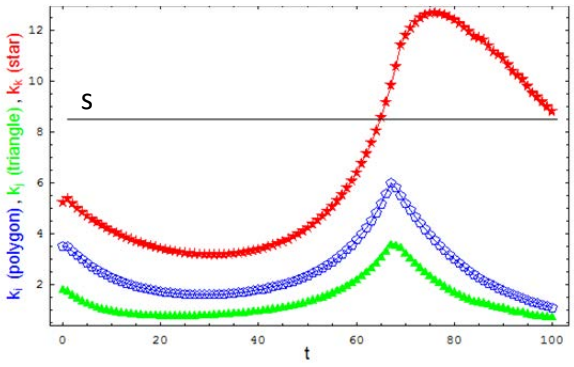


Fig. 26: Development of trust and knowledge Standard

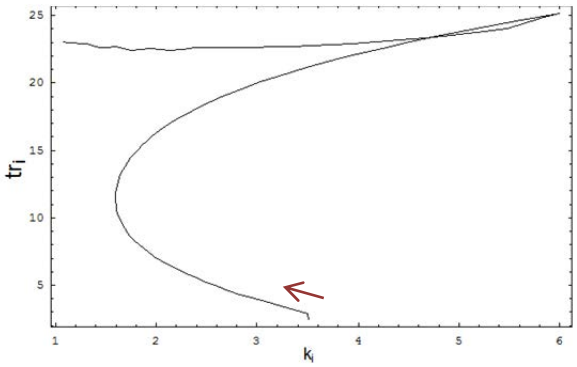


Fig. 27: Development of trust and knowledge *OPPORTUNIST*

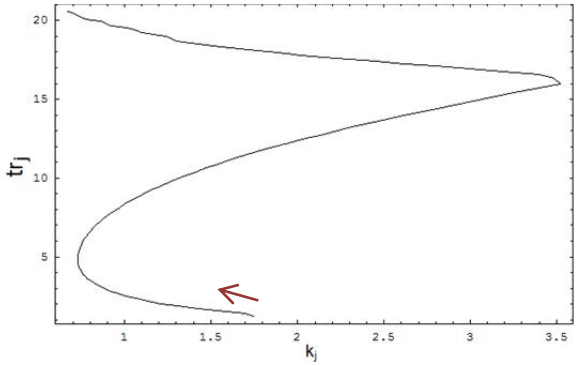
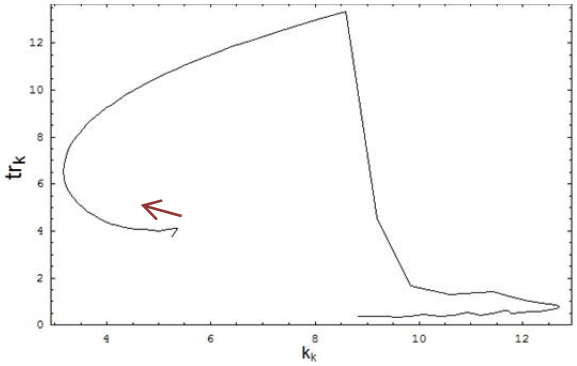


Fig. 28: Development of trust and knowledge *TRUST*



With regard to the default model and the group composition of scenario 2.3, the results show that the cooperations fail if π_i is enhanced at 0.5 respectively 2.0. For scenario 1.1, no effect occurs; these agents always seem to be able to gain just enough knowledge and trust to overcome the critical point.

Figure 23 - 28 show the simulation run with the three types of agents of scenario 2.3. The effect of the ´window of opportunity for defection´ for opportunistic behavior can easily be identified and is mostly due to a dramatic drop in trust of the agent TRUST in the 66th time-

step which leads immediately to a decline of the knowledge transferred and ultimately to the failure of the cooperation. STANDARD and OPPORTUNIST also experience declines in trust, but these declines are less considerable.

With regard to δ_i, the alternations of the values of the default model and of the model of scenario 1.1 do not affect the cooperations at all, as the agents gain enough trust and/or receive enough knowledge to overcome δ_i. This is different for the group composition of scenario 2.3. Here, the increase of the values of δ_i leads successively to higher numbers for *t(inno),* and with a value of 0.008 for δ_i, the cooperation fails. As can be seen in Fig. 29 - 34, from the beginning, the agents transfer only very small parts of knowledge, and the knowledge stock declines and regains value only slowly. TRUST recovers the losses only after the 77th time-step. The amount of trust between the partners is growing slowly, but alternates. These fluctuations amplify after time step 77 especially with regard to TRUST and the critical threshold which is reached with the 89th time step reinforces this process. The knowledge transfer is conducted accordingly, at least on the part of the agent types STANDARD and TRUST; OPPORTUNIST does not offer much knowledge at all. All in all, TRUST behaves the most erratically, which points to ´overoptimistic´ behavior and its resulting implications.

To summarize: The `window of opportunity for defection´ and the propensity not to tolerate non-reciprocity are of relevance for a cooperation if the respective values are pronounced. However, if agents are able to build up enough trust, critical situations might be overcome. A higher propensity to tolerate non-reciprocal behavior is of relevance in case the group composition is more heterogeneous and the behavioral values are more pronounced. Here especially the behavior of TRUST is affected and leads to an erratic pattern of behavior.

Fig. 29: Accumulation of trust

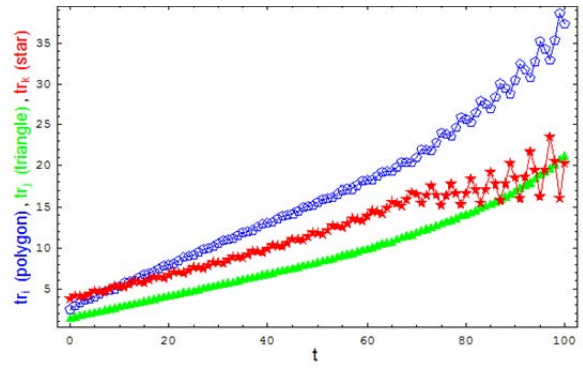


Fig. 30: Knowledge transfer

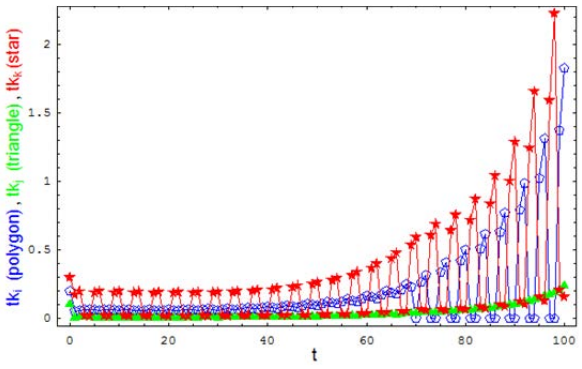


Fig. 31: Accumulation of knowledge

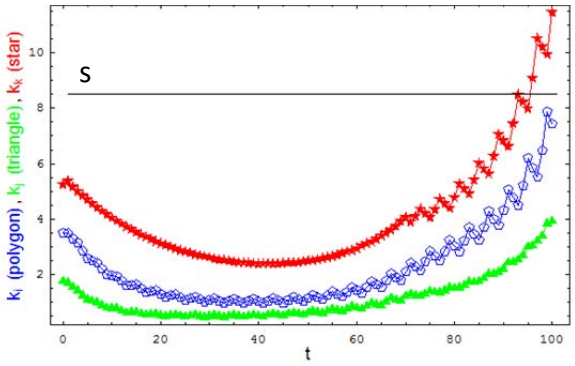


Fig. 32: Development of trust and knowledge STANDARD

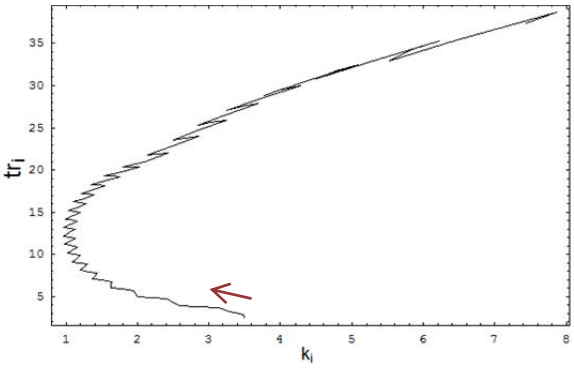


Fig. 33: Development of trust and knowledge OPPORTUNIST

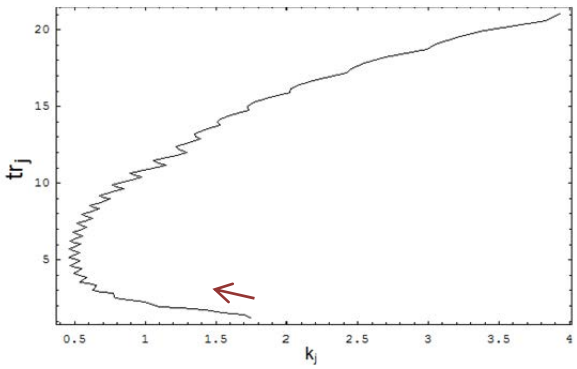
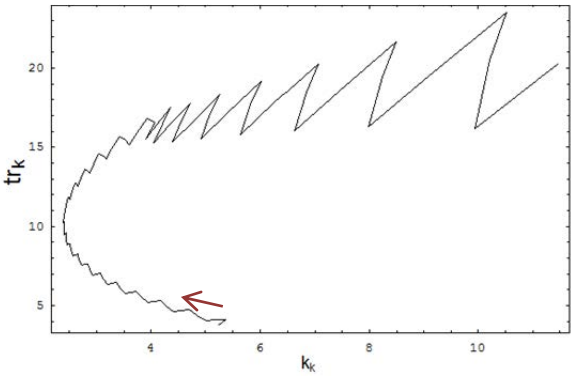


Fig. 34: Development of trust and knowledge TRUST



4.4.6. Summary, implications for further research and policy design

The aim of this study in general was to help establish a behavioral foundation for innovation research in the sense of Nelson (2012a), who points out, that there is still a research gap to be filled concerning the micro foundations of collaborative efforts. The study in particular aimed at facilitating a better understanding of the behavioral dynamics underlying collaborative R&D. The study used a threefold approach: *First* a behavioral model, the Kd-Td model,

was conceptualized; *second* the model was formalized by three differential equations; *third* these equations were applied in a computer simulation which simulated various multi-agent systems.

With regard to the conceptual model, procedural rationality as a more realistic alternative to the standard economics approach to human conduct was taken as behavioral foundation. Furthermore, based on Simon's consideration of docility, relevant findings of trust research were drawn on, merging both approaches into seven propositions embracing behavioral traits and processes as well as the specifics of R&D processes related to the behavioral perspective. Thereby, two basic distinctions were made, the differentiation of the knowledge dimension (Kd) and the trust dimension (Td) of collaborative R&D (hence the name of the model). The formal model accounted for the knowledge dimension by incorporating absorptive capacity and decay of knowledge. The trust dimension was accounted for by including the propensity to trust, to behave reciprocally and to tolerate non-reciprocal behavior.

Collaborative R&D is thereby understood as a means which allows bounded rational agents to circumvent their limitations by undertaking joint endeavors with others. This obviously presumes heterogeneity of agents. However, heterogeneity not only applies to cognitive capabilities, but also to the social behavior of agents. The present study takes this into account by setting up the simulation runs accordingly.

The result show, first of all, that the knowledge dimension is essential for conducting innovations, but that far better results can be realized through the interplay of both the knowledge and the trust dimensions. The findings, however, also show that because of heterogeneity the results of such interplays are uncertain. It becomes apparent that a high degree of heterogeneity with highly diverse values for the knowledge and the trust dimensions may sometimes lead very quickly to innovations, but also may induce ´overheated´ reactions resulting in the failure of a cooperation. In contrast, a lower level of heterogeneity accompanied by more moderate values for both, the knowledge and the trust dimension, may result in a longer duration of the cooperation before an innovation is achieved, but also reduce the likelihood of failure. And even if such a cooperation fails, the agents may be able to realize a net gain of knowledge and trust (which is of relevance for further cooperations and innovative endeavors). A more moderate group constellation of this sort may also make it possible to cope more effectively with opportunistic behavior and allow groups involved in collaborative

R&D to better handle such critical thresholds as the ´window of opportunity for defection´.

These results can be accounted for by making reference to the ´measure for measure policy' (Selten 1998). As far as bounded rationality allows, agents evaluate the difference between what they have given and what they have received in return. If the difference is within the realm of their expectations, cooperations can succeed. If, however, agents with high values in the knowledge and trust dimensions encounter partners less favorably endowed and/or agents who are behaving in an opportunistic manner, cooperation fails (see Fischbacher/Fehr, 2003). Hence, as Fischbacher/Fehr (2003) have also found, the composition of the group is crucial for success (Fischbach/Fehr, 2003). The results of the present study also point to the path dependency of the interaction, in keeping with the observations of Gächter et al.: The amount of the ´initial gift´ can be vital for success (Gächter et al., 2010). In summary, it is evident that knowledge sharing is indeed "a fragile process" (Gächter et al., 2010).

The findings of the present study could be very important for designing innovation policies. This study did not have the goal of developing corresponding policy instruments, but further research could certainly address this question. It is in any case evident from the findings that it is not sufficient to merely foster the knowledge dimension of innovation, as is so often done in today's innovation policies. What is needed in addition is a policy that addresses issues of trust among the cooperating agents. It could be argued that such instruments already exist within the policies designed to encourage the development of innovation networks. Partly this is so, but this remains a key area where the results of the present study point to the necessity of further development.

Against the background of these findings, a sharpened focus on establishing the `right´ group composition is therefore of particular relevance. The concrete details of such a composition, that is, which kind of agents should be involved, could very well vary with regard to different goals perused by innovation policies. If it is of relevance to achieve very quick results (while risking failure), then the obvious choice would be to go for the 'best' agents, taking the risk of ´overheated´ reactions into the bargain. If the goal is to foster long-term, repeated cooperations, then more moderately endowed agents would be more suitable.

Finding the ´right´ group composition will, of course, not be easy. As we know, bounded rationality also applies for policy makers. Therefore it might be worthwhile to develop instru-

ments which aim at designing possible corridors of characteristics for the process of composing groups. Other policy-relevant issues include critical points occurring in the course of a cooperation, such as the ´initial gift´ and the ´window of opportunity for defection´. These moments in a cooperation could be addressed through well designed policy instruments that focus on the first and the last steps of a collaborative interaction.

All these considerations point to the need of further research as well as to the limitations of the present study. This study is restricted to the analysis of the behavior of artificial agents in singular cooperations with a limited setting of behavioral variables and parameters, without any environmental influences and/or other restrictions. An extension of the model, for instance with regard to repeated cooperations and/or an analysis of the possible impact of diverse instruments thus could be fruitful. This, however, would require the development of a systematic evaluation of the results in order to identify the singular and the combined relevance of behavioral variables and parameters. Furthermore, empirical research could usefully be conducted in order to analyze the behavior of real agents. The findings of the present study and further simulation models might give new starting points for the evaluation of particular aspects of such behavior. Research along these lines would certainly be in keeping with the concerns of Herbert Simon and might provide a significant contribution to the further development of innovation research.

4.5. Agent Based Modelling of Novelty Creating Behavior and Sectoral Growth Effects – Linking the Creative and the Destructive Side of Innovation* (Artikel 5)[100]

4.5.1. Introduction

Obviously novelty creation[101] is a two sided process: it is ‚creative' and ‚destructive' at the same time. The background for this two-sided nature is that novelty creation has to overcome obstacles and, if it succeeds in doing so these obstacles will be eroding therefrom, generating some individual or social costs. The main focus of this elaboration is on the obstacles for novelty creation, on the individual level in terms of routines, and on the sectoral level in terms of sticky demand both indicating well established and learned forms of behavior. Hence, the main question to answer is: What are the driving forces in favor of novelty creation and under what conditions are these driving forces strong enough to overcome the inertia of established behavior?

To assume that there is a given frequency of novelty creation and simply to suppose diffusion effects in sectoral terms would only be a partial answer to the question. Due to the inherently uncertain nature of the outcome of novelty creation, the conditions favorable for its occurrence have to be included in the analysis. Furthermore, the type of initial novelty creation (e.g. its individual or co-operative nature, or the distinction between innovation proper and imitation) is important for the dynamics of its social dissemination. Hence, a fully fledged concept of novelty-driven aggregate growth has to include

- the triggering conditions for novelty creation,

*This research was supported by the Volkswagenstiftung. Comments by an anonymous referee and programming assistance by Ramón Briegel are gratefully acknowledged.

[100] See for the pseudo code Appendix 7.4.

[101] In this article, we distinguish the notions of „novelty creation", „imitation" and „innovation". By the generic term „novelty creation" we integrate all aspects of th e creation of new products in firms. This encompasses *radical product innovation* (simply called „innovation" in the sequel) as well as, according to the definition of OECD, Eurostat (2005, p. 46), „imitations" which comprise innovations that are new at the level of the firm, but not for the market. Our definition of novelty creation takes a broader scope than the definition provided by Witt (2009, p. 312), who refers to fundamental novelty. On the other hand, our notion is narrower than Witt's as we refer only to product innovations. (These may involve physical products and/or services.)

- the type of novelty creation and
- the dynamics of sectoral dissemination (diffusion).

Obviously, such an analysis is at least about two levels of economic activities and their inter-relation.

This contribution tackles such a multi-level analysis. As regards the triggering conditions for novelty creation, a special emphasis is put on behavioral factors. Whereas external triggers in terms of scientific insights, environmental conditions or political regulations are thoroughly investigated (cf. Clarke/Weyant 2002 for a survey), the internal behavioral trigger elements are under-represented in the literature on novelty creation in general (exceptions: Shackle 1961; Scitovsky 1976; Witt 1987; March 1994; Morrison/Potts 2009) and especially in the literature on growth.[102] This is the more surprising given that the more attempts have been made to endogenize the explanation of growth by integrating the dynamics of novelty creation into the realm of growth theory. Specifying the behavioral trigger conditions for novelty creation (in terms of personal traits, on one side, and of individual variables on the other side) is the main task on the micro-level for analyzing the emergence of growth.

Against this background, this contribution aims to *first*, shed light on the micro-foundation for novelty creating activities, and *second*, show the interplay between the micro-level of firms and the sectoral level of economic activities. On both levels, novelty creation is not simply conceptualized as an add-on to given activities (which would imply a too simplistic view of the growth effect), but rather as an overcoming of given routinized activities and/or established products. Hence, specifying the devaluation or even destruction (in economic terms) as the other side of novelty creation is the *third* aim of this contribution. *Finally*, it will be shown how at least some basic stylized observations can be confirmed by such an analysis of the growth process: novelty creation as a temporary activity of a changing part of the whole economic population and persistent heterogeneity of actors in terms of behavior and economic performance.

In pursuing these aims, we generally follow the path of evolutionary thinking (Silverberg/Verspagen 1995, 4; Dawid 2006, 1243), taking into account that a twofold property of

[102] The so-called endogenous growth theory is the most prominent example for such an endeavor.

economic activities is at the core of such an approach: on one side, they are characterized by well established procedures and routines being backed by past experiences, while, on the other side, these activities are taking place in a dynamic selection environment urging the actors from time to time to search for new knowledge and corresponding new ways to act. Hence, on the individual as well as on the sectoral level, a breaking of routines and – as a possible consequence – a change of product properties as well as of exchange relations is occurring. In that sense, the creation and dissemination of knowledge is an important driver for economic evolution. According to this dynamic property, the actors in their entirety consist of different components as regards their behavioral status. They form a population the composition of which is changing over time. The most important hypothesis of an evolutionary approach to growth is that this time-dependent composition of the population as regards novelty creation mainly explains the time path of observable aggregates.

The sectoral growth model we are suggesting can be classified as a model in the tradition of Nelson and Winter (Nelson/Winter 1982; Chiaromonte/Dosi 1993; Silverberg/Verspagen 1994). In these models, the expenditure for novelty creating activities of firms is assumed to be the most important control variable. The experienced performance in the market competition is seen as the main factor influencing the setting of this control variable. The corresponding search activity of the firms takes place in a ‚bounded' way (normally specified as ‚local' search) resulting from the limited knowledge about the search space in which the firms are operating. Firms that are successful in such a search process have a comparative advantage over less successful firms. They gain additional profits and investment opportunities, both increasing their survival probability in the market.

But there are also a lot of features distinguishing the suggested model from the standard Nelson/Winter approach. It has a strong behavioral foundation in that the ability of firms to act is conceptualized in different modes of action.[103] According to the above mentioned twofold property of economic activities, every novelty creation has to overcome the routine mode to act and takes place in a specified manner as individual innovation or imitation or as

[103] A mode of action is defined by a particular way to care about information, to discriminate between alternatives and to link different practical operations.

a cooperative innovation.[104] These different modes to act are fed by different behavioral forces, being composed of (constant) personal traits and (variable) factors on the individual level. In that sense the occurrence of the intention to create a novelty as well as to pursue it in a specific mode of action is endogenized in behavioral terms in the suggested model architecture. This accomplishes the attempts in the literature to model novelty creating agents being endowed with different modes to act, in that the selection of these modes of action is now not merely determined by a given probability distribution (cf. Fagiolo/Dosi 2003) or derived from sectoral performance requirements (cf. Dawid et al. 2001; Llerena/Oltra 2002). Furthermore, in the model suggested here, the different modes to create novelty encompass different forms of knowledge acquisition and different effects of these knowledge augmenting procedures on sectoral growth. Due to this focus, the technical dimension of evolutionary change is not explicitly dealt with.[105] Rather, the latter is conceptualized in a disembodied manner (Silverberg/Verspagen 1995, pp. 4) in assuming that additional knowledge – as an ability to improve product quality – is tantamount to an access to additional market potential. This market potential is determined on the individual agent-related level. According to the usual spreading dynamics of information in the diffusion process (cf. Rogers 1995) it is assumed that this market potential for an improved product unfolds in an s-shaped manner in the course of time. Furthermore, the access to this market potential is influenced by agents imitating this improvement and by agents innovating later on, inducing a partial substitution of the demand for older products. Hence, the firm's overall access to the market potential is determined by different time-dependent layers of knowledge. Therefore, the model implicitly incorporates vintage effects and product differentiation.[106]

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[104] In the given context, ‚individual' means ‚one firm' and ‚cooperative' means at least two firms interacting directly.

[105] Apart from that tackling a technologically embodied change is not an easy analytical task for which a well defined solution recipe exists (Silverberg/Verspagen 1995, p. 9).

[106] Product innovation was introduced in a Nelson/Winter framework for the first time by Gerybadze (1982). Recently, Dawid and Reimann 2010 used an approach similar to the one suggested in the present contribution in a model on product diversification. In their model, the demand potential of a sub market is functionally dependent on the firms innovative efforts (measured in terms of r&d investments). This potential determines the attractiveness of a product variant. The attractiveness of each product variant changes according to a function in which time enters as an independent variable.

To summarize: for grasping the relationship between novelty creating activities of agents and growth of economic aggregates, a *multi-level approach* is suggested. The *first* level specifies the triggering conditions for novelty creating activities for the agents (i.e. firms). Here, the behavioral elements and the modes of action for the firms are portrayed by using an agent-based approach (Section 4.5.2). On the *second* level, the consequences of successful innovations and imitations in terms of their dissemination effects in a given sector of economic activities are dealt with (Section 4.5.3). These depend on the frequency of successful novelties and on the way they diffuse in that sector. As regards the supply side, we use an agent-related approach to depict the stylized facts of the diffusion dynamics. The demand side is not dealt with in an agentbased manner, but rather by making plausible assumptions about its dynamics. Deriving aggregate effects of novelties for the whole economy necessitates distinguishing between these different levels of economic dynamics as well as relating them to each other.[107] This will be done by way of computer simulations (Section 4.5.4). Conclusions are drawn in Section 4.5.5.

4.5.2. Agent-based modelling of behavioral innovation triggers

4.5.2.1. Behavioral analysis of innovation activity

Under what conditions and in what way do agents create novelties or – in knowledge related terms – under what conditions do agents search for new knowledge? Setting aside a principal methodological caveat against this question,[108] there are two types of answers to it. In the ‚functional approach' (mainly originated in the work of Hayek), a strategic (first mover) advantage for successful creators of novelties is derived from competition. From this assertion, it is directly concluded that there is a person/an agent who makes use of this advantage. In the ‚personal approach' (mainly originated in the work of Schumpeter), it is assumed that there is a specific type of agent whose main profession is to innovate, i.e. the entrepreneurs.

107 This procedure manifests the importance of the multi-scale property for analyzing the economy as a ‚complex adaptive system' (Arthur et al. 1997).

[108] According to this caveat, the novelty creating process is totally conjectural without anything to generalize. Due to the idiosyncratic nature of the processes, as well as of the persons involved in innovations, some authors see only a limited possibility for an after-the-fact analysis on an aggregated level (Vromen 2001). For a critical discussion of these assumptions cf. Beckenbach and Daskalakis (2003, pp. 3).

Both approaches are not sufficient in explanatory terms. The personal approach neglects the fact that innovating is a temporary activity which principally can be attributed to every economic agent. The functional approach fails to explain why, in a given time span, only a part of a whole population linked by a competitive process is in fact innovating and what kind of motives these innovating agents have.

The reason for this explanatory gap might lay in the above mentioned methodological caveat against the possibility of a microanalysis of novelty creation, which follows from the paradox that the unknown consequences of novelty creation make it difficult or impossible to analyze such a process. However, this gap of explanation exists only as long as we regard the material or immaterial outcome of innovative processes. If, however, we conceptualize novelty creation as a specific way to act (having a contingent outcome), there are possibilities to analyze the determinants of the selection of this type of action. Such analyses might help to get a better understanding of innovation.

An approach of this type is confronted with the problem that evolutionary economics does not yet offer a satisfactory theoretical framework for it (cf. Endres/Woods 2010). The Carnegie School, however, does provide such a perspective on entrepreneurial acting. In the present context, the Carnegie approach is important in (at least) three respects: *First*, the approach sheds light on the determinants of the selection between the two relevant modes of action: routine acting (as the default mode of action) and search (in terms of shifting from persistence to change through novelty creation). *Second*,the decision units (especially firms) are not conceptualized as being internally consistent, but rather are seen as entities with internal conflicts being moderated in different ways and reaching common goals (Cyert/March 1992, p. 162, pp 229).[109] *Third*, a common denominator of the features of a decision unit is its limited ability to perceive information, and to transform this information into activity. This gives some hint as to how to specify novelty creating activities in behavioral terms.

According to the Carnegie School, the basic action mode of firms is routine acting. This action mode is continued at least as long as the degree of goal attainment is compatible with

[109] This focus allows for deriving characteristics on the firm level from characteristics at the individual level.

the aspiration level of the firm (March/Simon 1993, p. 205). Thereby it is supposed that the dimension of the firm's goals (i.e. in terms of production, inventory, sales, market share and profit (Cyert/March 1992, pp. 46-49)) are formed in complex and conflictladen processes between individuals and subgroups of the firm (Cyert/March 1992, pp. 33). The aspiration level is set up as a weighted mean of the following three variables: „the organization's past goal, the organization's past performance and the past performance of other ‚comparable' organizations" (Cyert/March 1992, p. 162). These aspiration levels are changing over time according to the current level of goal attainment and the perceived competition (March/Simon 1993, p. 204; pp. 33; March 1994, p. 29), leading to an adaptation of goals in its different dimensions (Cyert/March 1992, p. 172).

The comparison between the degree of goal attainment and the aspiration level (i.e. the degree of satisficing) is a core topic of the Carnegie School because it is supposed that the non-attainment of goals is triggering distinct entrepreneurial decision processes within the firm. In this context, we have to distinguish between two types of decision situations: on one side, there are situations in which a decision is made out of a given number of known alternatives; on the other side, there are situations characterized by the fact that the specific properties of possible alternatives are not known ex ante (March/Simon 1993, p. 195). The latter type of decision situation is a characteristic feature of innovation proper and is the focus of our analysis.

Following the assertions of the Carnegie School, innovations as search for new action alternatives can be triggered by falling short of as well as by exceeding the aspiration level („satisficing search"; March 1994, p. 31; March/Simon 1993, p. 205). Here it is supposed that – due to its urgency – an innovation triggered by falling short of the aspiration level („failure-induced search"; cf. Cyert/March 1992, pp. 188; March/Simon 1993, pp. 203) is more goal-directed and efficiency-oriented than a „success-induced search" (March 1994, p. 34) which is triggered by exceeding the aspiration level. The latter type of search requires the existence and availability of free resources („slack") within the firm (which so far had only been used inefficiently) (March 1994, p. 34; Cyert/March 1992, pp. 188; March/Simon 1993, pp. 203; Levinthal/March 1982, p. 189). Due to its surplus in terms of resources, the success-induced search (also called slack search) is less restricted and therefore allows for more radical innovations than the failure-induced search (Levinthal/March 1982, p. 189; March 1994, p. 34).

However, falling short of or exceeding the aspiration level does not necessarily induce a search for new action alternatives. An adaptation of the aspiration level (reduction in the former case, increase in the latter case) can lead to persistence of the dominant action mode of routine.[110] One possible reason is that innovations are considered as sunk costs which can be avoided by continuing the routine mode (March/Simon 1993, p. 194; Simon 1997c, p. 89). So the question arises which factors are crucial for firms' switching into search mode instead of sticking to a routine, even in case of not attaining or exceeding the aspiration level?

One such factor is risk acceptance (cf. March 1991a, p. 101; 1994, pp. 35-55).[111] Since the outcome of search processes is per se unpredictable and since search involves some costs, the risk acceptance of firms (resp. of decision makers within firms) determines the willingness to initiate search processes. Two aspects are relevant in this regard: Risk acceptance depends on individual factors and on the (perceived) situation. March (1994, pp. 42) distinguishes between three classes of situations, depending on the degree of aspiration fulfillment: If the goal attainment exceeds the aspiration level or falls short of it, the risk acceptance is relatively high. If the aspiration level is met approximately, risk acceptance is lower, i.e., decision makers choose less risky strategies.

Corresponding to these different risk attitudes, it is possible to distinguish between more and less risky search strategies. Assuming that search processes for innovations can be conceived as problem solving processes (March/Simon 1993, pp. 197), a distinction can be made between two types of such problem solving: productive and reproductive problem solving (cf. March/Simon 1993, p. 198). The former involves the creation of fundamentally new options (‚exploration'); the latter aims at processing options that are more or less existing, but not yet used (‚exploitation') (March 1991b, p. 71; 1999, p. 184; 1994, p. 273; 2006, p. 205). Whereas exploitation is characterized by rather general features such as „refinement, choice, production [and] efficiency" (March 1994, p. 273), explorative processes are assigned to the above mentioned risk acceptance as well as more features pointing at a special (creative)

[110] Exceeding the aspiration level can also lead to a reduction of search activities of a firm (cf. March 1994, p. 31; Cyert/March 1992, pp. 41; March/Simon 1993, p. 194).

[111] For a discussion of the risk conceptions of managers, see March and Shapira (1987).

propensity to discover something new: „experimentation, play, flexibility [and] discovery...“ (March 1994, p. 273).

It becomes apparent that search processes, especially exploration resp. productive problem solving processes, require a high level of organizational capacity and skill of the members of the firm. With regard to the restriction imposed on the success of a problem solving process by bounded rationality (i.e. in terms of available knowledge), the Carnegie School also emphasizes the relevance of group problem solving (cf. March/Simon 1993, p. 173, pp. 201). Group problem solving allows for saving time by subdividing parts of the problem, for gaining access to different skills, for reducing error through communication, and for enhancing the quality of the solution (cf. March/Simon 1993, p. 202, p. 215; cf. also Marengo et al. 2000; Okada/Simon 1997).

However, the ability of a single firm to conduct group problem solving is restricted by time and skills. Furthermore, the „knowledge explosion“ (March 1999, p. 181) which characterizes modern economies constantly increases the amount of (new) knowledge necessary for survival. Therefore, organizations have to consider whether they pursue the search endeavor alone or set up a (temporary) partnership with other firms. Unfortunately, the Carnegie School has little to say about this topic, as it predominantly deals with processes within organizations. But the huge body of research conducted to analyze innovation networks[112] gives evidence for the relevance of the topic. From a problem solving point of view, such cooperation might also be seen as a form of group problem solving (Daskalakis/Kauffeld 2007, 7; von Hippel 1990). Such cooperation constitutes a win-win situation for firms, as long as the players are competent, trust each other (Klimoski/Karol 1976; Noteboom 2004, p. 100; McEviliy/Zaheer 2006), and behave reciprocally by displaying relevant knowledge (Daskalakis/Kauffeld 2007, pp. 9, p. 17), and as long as the transaction costs required for setting up and maintaining the cooperation do not exceed the (presumed) gains (Beckenbach et al. 2009, p. 82; Lorenz 1999). It can be theoretically expected and empirically observed that firms exhibit heterogeneous attitudes towards engaging in a cooperation (Beckenbach et al. 2009, p. 85; Daskalakis/Kauffeld 2007, pp. 14).

[112] We use the term in a broad sense, including the notions of cooperation, national and regional innovation networks, clusters, industrial districts, and so on.

If a firm is involved in a process of group problem solving, three conditions have to be considered: *First,* there has to be a basis for communicating in terms of a mutual stock of knowledge being part of each involved firm; *second*, as the purpose of group problem solving lies in the exploitation of different skills, cognitive distance or complementary cognitive endowment as proposed by Noteboom (Noteboom 1992, p. 297; 2004, pp. 21; Noteboom et al. 2007) might be required; and *third* the knowledge must have the attribute of being transferable.

To sum up, the aspiration level plays an important role for the initiation of decision processes concerning the choice between continuing the current action mode (routine acting) and the introduction of a new action mode, namely innovation. With regard to the differentiation between successinduced search and failure-induced search as well as between productive and reproductive problem solving, at least two degrees of novelty inherent in innovation can be distinguished. The success-induced driver for search and the corresponding productive problem solving aim at a high degree of novelty and the introduction of new products. The failure-induced driver for search and the corresponding reproductive problem solving are primarily focused on improving existing products (of the firm itself) or on imitating products of the firm's competitors. Individual characteristics such as risk acceptance and other specific factors (which can be grasped by the notion of „exploration drive") play a crucial role in the decision on the degree of novelty to be created. Finally, the degree of complexity of modern problem solving processes requires a choice as to whether the search process is to be conducted alone or in cooperation with other firms.

4.5.2.2. Architecture of the agents in the simulation model

4.5.2.2.1. Individual modes of action and their triggering conditions

The behavioral background features for innovation activities of firms emphasized by the Carnegie school are incorporated in the present modeling of agents. It is assumed that the firm-agents pursue two goals, profit and market share, for each of which an aspiration level is set. According to the above mentioned insights, the firms are able to perform three modes of action: routine behavior (as default mode), imitation and innovation. Whether an agent leaves the default mode of routine and what kind of novelty creation is selected, depends on different feasibility conditions and on behavioral forces composed of indicators for the goal

attainment (in terms of the aspiration level), expected cost for the target activity, and the amount of slack.

Before any kind of novelty creation can be pursued by the firm, the financial feasibility has to be checked. This is done by comparing the current liquidity and the profit expected from the novelty creation[113] on one side, and the expected costs of novelty creation on the other side.[114] If the latter are covered, the novelty creation is classified as feasible.[115]

According to the concept of the Carnegie-school sketched above, the basic driver in favor of novelty creation is assumed to be the relationship between goal attainment in terms of profits (p) and market share (m) and the respective aspiration level (asp, asm). In formal terms, this means[116]

$$f_1(t) = w_1 \left(\frac{asp(t)}{p(t)} \right)^{\varepsilon_1} \tag{1}$$

$$f_2(t) = w_2 \left(\frac{asm(t)}{m(t)} \right)^{\varepsilon_2} . \tag{2}$$

In each time step, the aspiration levels are updated according to:

$$asp(t+1) = (1-\varphi)\, asp(t) + \varphi\, p(t) \tag{3a}$$

$$asm(t+1) = (1-\varphi)\, asm(t) + \varphi\, m(t) \tag{3b}$$

where φ is the flexibility of adaptation, which is another individual trait of the firms ($0 \le \varphi \le 1$) reflecting the relative weight attached to past and present performance. The force in favor of *failure induced search* (corresponding to imitation) can be formalized then by relating the sum of f_1 and f_2 to the expected costs of an imitation project:

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[113] The expected profit is calculated by a linear regression on past profits weighted by a parameter reflecting angent-specific degrees of optimism/pessimism.

[114] The expected costs are calculated by multiplying the given costs per time step and the average time for novelty creating processes. According to empirical findings, it is assumed that the costs of an imitation project are lower than the costs of an innovation project.

[115] If the novelty creating process is intended as an imitation, the knowledge about another firm's product (improvement) which appeared recently in the market is required as an additional feasibility condition.

[116] For reasons of model fine tuning, these relationships are formalized as elasticities (power of ε) with different weights (w).

$$F_1(t) = \frac{f_1(t) + f_2(t)}{cim}. \quad (4)$$

In the case of *success induced search* (corresponding to innovation), f_1 and f_2 will be low. Specifying the triggering conditions for innovation, therefore, necessitates take into account other factors such as slack, risk and the willingness to explore. Considering reserves in terms of financial resources (fr) and in terms of knowledge (kr)[117] as the main sources for slack, and conceptualizing the exploration drive (w_0) as a weighting parameter for this slack, the component in favor of innovation can be formalized as:

$$f_0(t) = w_0(kr(t) + fr(t)). \quad (5)$$

Summing up this additional component and the factors for failure induced search (which still have a weak influence) and relating this sum to the expected cost of an innovation project is tantamount to the innovation driver. Integrating the risk attitude (α) as a weight for this driver gives the formal expression for the forces in favor of innovation:

$$F_2(t) = \alpha \frac{f_0(t) + f_1(t) + f_2(t)}{cin}. \quad (6)$$

Taking the routine mode as the default mode of activity (to overcome by novelty creation)

$$F_0(t) = 1 \quad (7)$$

as a reference value,[118] the actual mode of action pursued by the firm (F_{am}) is determined according to the condition:

$$F_{am}(t) = \max(F_0(t), F_1(t), F_2(t)). \quad (8)$$

To allow for heterogeneity in the population with regard to the behavioral parameters the firms are subdivided into three different types: *first,* conservative firms, being more aversive against changes, hence fostering routines; *second,* cautious firms, which prefer imitation; and

[117] The knowledge reserves (kr) are operationalized as the relation of the number of sharable knowledge domains (see below) of the agent to the total number of sharable knowledge domains; the financial resources (fr) are operationalized as the share of the current profit in relation to current turnover.

[118] Setting the preservation force as a constant is no restriction of generality since the absolute values of the forces F_i do not matter; it is only the ratio between them which determines the action mode. There are three special or exceptional cases in which the selection mechanism mentioned above is not applied (or even not applicable) two of which concern start up firms and one concerns firms with a negative or zero profit. (See Beckenbach et al. 2009 for a more detailed discussion.)

third, experimental firms, which are more likely to pursue innovations. The firms differ with respect to the behavioral parameters α, w_0, ε and φ. The distribution of the type of firms as well as the values of α and $w_{0...2}$ are derived from an empirical investigation of the novelty creating behavior of German firms (Beckenbach et al. 2009).

4.5.2.2.2. Cooperative innovation

A firm agent who has selected the action mode of innovation still has two options (see above): He can try to develop an innovation on his own (individual innovation) or he can seek cooperation in order to enable or facilitate the development of an innovation.

Analogously to the selection mechanism between the three action modes (discussed in Section 4.5.2.2.1) and the selection between individual and cooperative, innovation is determined by a comparison of forces: Denoting the propensity to cooperate by χ and the share of cooperative innovations N_c (related to the total number of innovations N) by $\frac{N_c}{N}$, the cooperation force of an agent is given by:

$$cp(t) = (1 - ifb - if\ f)\chi + ifb\frac{N_c(t)}{N(t)} + if\ f\sum_{i=0}^{2} f_i(t), \tag{9}$$

ifb and iff being parameterized weights for the different triggering forces. Actually, a firm agent is willing to cooperate if this cooperation force is larger than a threshold (*ct*):

$$ct < cp(t). \tag{10}$$

Given the willingness of an agent to cooperate, a matching procedure takes place to determine if a cooperation can actually be formed. The *matching conditions* concern the existing relationship between firm agents, as well as some knowledge requirements. As to the relationship between firm agents, it is required that the partners for a cooperation should either belong to the same branch or that they be related to each other as suppliers or customers.[119] Moreover, potential partners to whom an agent has a high level of trust are preferred because trust facilitates the exchange of knowledge and reduces transaction cost. As to the knowledge requirements, there is a condition that requires a certain amount of common (non-rivalrous) knowledge (accessible at low costs), ensuring a common basis to communi-

[119] At the beginning, each firm is assigned randomly a set of supplier firms, being fixed for the whole simulation.

cate within the cooperation process, and another condition that requires a certain amount of complementary (specific) knowledge (accessible only at high costs), constituting an incentive for knowledge exchange. The overall matching of firms in the process of co-operative innovation is summarized in Fig. 35.

Once a cooperation has been formed, a process of knowledge transfer starts. This process lasts a fixed number of time steps (the development duration of an innovation), in each of which knowledge in one domain is transferred from one agent to the other with a certain probability. This probability (pb) depends, on the one hand, positively on the trust (tr) of the knowledge-giving agent in the knowledge-receiving agent and, on the other hand, positively on the absorptive capacity (*ac*) of the receiving agent.[120] Formally, the probability is given by:[121]

$$\mathrm{pb}(t) = se\,(\mathrm{tr}(t) - 1) + ac\,, \tag{11}$$

where *se* denotes the sensitivity of the probability of transferring knowledge with respect to trust.

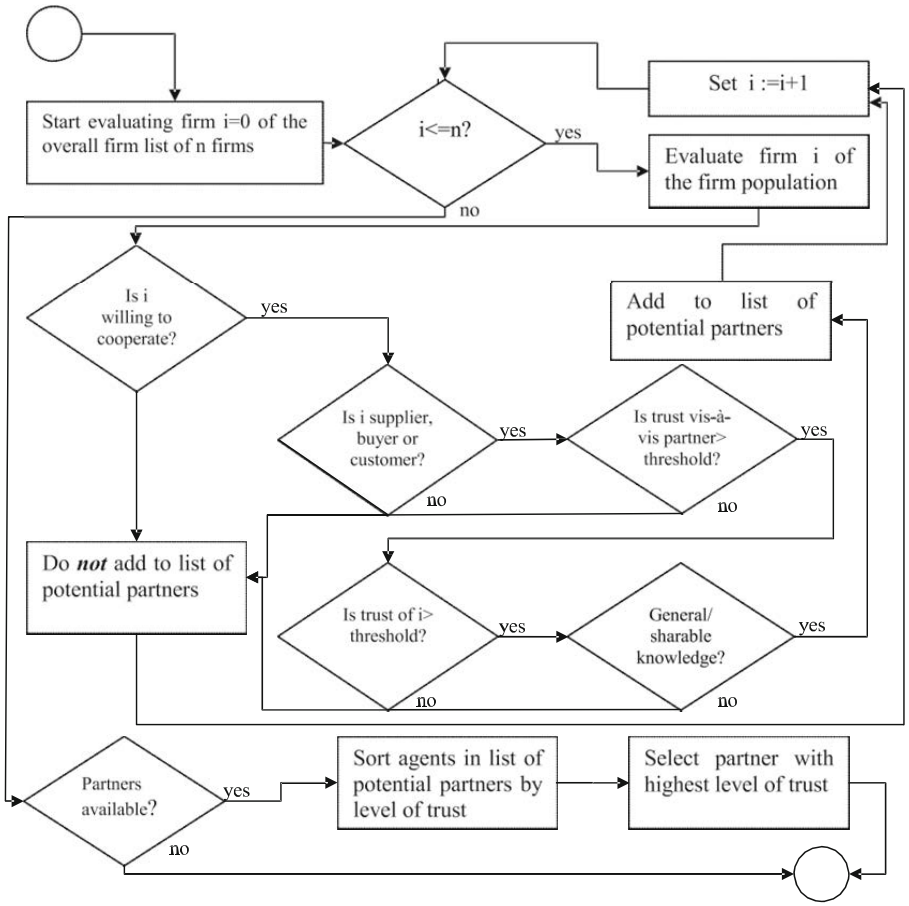
Each time this knowledge transfer does not happen, the trust of the second agent in the first is diminished by a certain decrement; by contrast, trust is raised by a certain increment each time the transfer actually happens. If trust falls beyond a certain threshold, the second agent breaks off the cooperation and abandons this innovation project. If there remains more than one agent from the current cooperation and if these agents have successfully exchanged some knowledge, they continue the cooperation. The decrement and increment of trust as well as the threshold are model parameters. Each step of this transfer process has a certain cost for both partners.

[120] The absorptive capacity is conceptualized as a given probability weight for the cooperation to happen.

[121] If the right hand side of the equation is negative, the probability is set to 0. We assume $0 \le tr \le 1$ and $0 \le ac \le 1$.

If the transfer process is successfully accomplished, an innovative product is created and put on the market, as described above. Production costs and returns are shared equally among all partners.[122]

Fig. 35: Matching of firms in co-operative innovation



4.5.3. Dynamics of diffusion on the sectoral level

4.5.3.1. Conceptual foundation

Diffusion is the process by which innovations are adopted by users within a population of agents (Jaffe et al. 2003). In this regard, a basic but important observation is that diffusion is time consuming. Moreover, the diffusion process typically produces a characteristic S-shaped curve if the number of adopters is plotted against time (Dosi 1991; Rogers 1995). In the empirical literature, several other factors have been analyzed that explain both scope and speed

[122] Independently of the knowledge transfer described above, there are two probabilistic „knowledge destruction“ processes taking place in each time step: a decay (forgetting) of knowledge for each firm and a general devaluation (depreciation) of knowledge for all firms as a global effect of technological change.

of innovation diffusion (Griliches 1957; Mansfield 1968; Gort/Klepper 1982; Rogers 1995; Grübler et al. 1999). Insights from this literature include (among others) the observation that diffusion hinges on the aspects of the underlying technology (both the innovative technology and the technology to be substituted), environmental incentives, the characteristics of adopters, as well as the spreading of information (Dosi 1991).

In the modelling of diffusion at least three influential approaches can be discerned (cf. for surveys Metcalfe 1988;Dosi 1991; Kemp 1997; Geroski 2000; Jaffe et al. 2003). *First*, epidemic models, which consider the diffusion process in analogy with the spreading of an infectious disease. This modelling approach particularly stresses the importance of the spreading of information as a prerequisite for adoption. The model itself was mainly criticized for not delivering (micro-founded) explanations for the adoption of innovations (Dosi 1991).[123] *Second*, there are so-called probit models which explicitly take into account the adoption decisions of the agent – usually in the form of choice based on optimizing behavior (Kemp 1997, p. 80). Hence, in these models, aspects of learning and interaction within the population of agents do not play a prominent role. A *third* approach is given by agent-based models of innovation diffusion (Silverberg et al. 1988, Windrum/Birchenhall 2005, Schwoon 2006, Schwarz/Ernst 2009, Wittmann 2008, Windrum/Birchenhall 2009a, b). In these models – mostly related to products with different environmental qualities – the interaction and decisions of heterogeneous agents are an integral part of the modelling concept. Considering the criticism regarding the other categories, agent-based models have the advantage of capturing both the heterogeneity of the potential adopters as well as the particularities of various forms of interaction (including knowledge transfer). For this reason, they can provide micro level details for the analysis of innovation diffusion.

Apart from the spreading dynamics for the innovation itself, the diffusion dynamics is strongly influenced by the conditions for exit and entry in a given sector. The intensity of competition, on one side, and the financial constraints, on the other side, are considered to be most influential in this respect (Dosi et al. 1995; Agarwal/Gort 1996).

[123] Cf., however, Geroski (2000) for an exposition of how a basic diffusion model can be enriched to incorporate heterogeneity on the part of the adopting agents.

Because the main focus of our agent-based perspective is on explaining the occurrence of novelty creations in different forms, the explanation of the diffusion dynamics suggested here combines stylized facts of diffusion research and agent-based analysis: A successful novelty creation on the individual level (in terms of product improvement) triggers a demand dynamic for this product. If initially a critical mass for this product is overcome, a self-feeding diffusion process up to a maximum level in which all market potential is exhausted takes place. According to the dominance of retarding effects at the beginning of this diffusion process, and due to the dominance of the promoting effects at later stages, an s-shaped time-dependent diffusion curve is assumed (Rogers 1995). Finally, the twofold nature of economic activities (see Section 4.5.1) necessitates giving innovations a twofold sectoral effect: a growing of the demand for the products of an innovating firm and a substitution effect for older products. Hence, the overall diffusion process is not simply postulated or constructed but is strongly shaped by the type and the time in which the novelty creation is occurring on the individual level.

4.5.3.2. Features of the diffusion process in the simulation model

The starting point of the diffusion dynamics is the emergence of an innovation (developed according to the agent-based explanation in Section 4.5.2.2). As innovations are high risk ventures, we assume that there are two possible outcomes of a diffusion process:

- on the one hand, there are certain innovations successfully diffusing in a population by successively increasing their share of demand;
- on the other hand, there are innovative failures which may temporarily attract some demand, but finally fail to diffuse on a large scale.

Formally, we discern between these two outcomes by calculating a demand potential (ypo) that represents the total demand possible for an individual innovation. The demand potential functionally depends on the current turnover of the innovator (u) as well as the amount of knowledge with which the innovating agent is endowed (k). The assumption behind the last point is that a broader knowledge base is correlated with a higher flexibility as well as a better ability to meet the demand. This superior knowledge-dependent ability of an agent is assumed as giving access to a higher demand potential (ypo) for the agent's products:

$$ypo(t) = u(t)k(t)\,\lambda_1 \qquad (12)$$

where λ_1 is a stochastic term depicting market uncertainties. In our model, *successful innovations* are those for which the initial demand potential exceeds a threshold value yts. We assume that

$$\text{yts}(t) = \text{ypo}(t)\,\lambda_2 \tag{13}$$

where λ_2 again is a stochastic term depicting market uncertainties. Given this constellation, the demand gradually approaches the demand potential as the simulated time progresses. A parameter *v* regulates the speed of this process for successful innovations, which can be formalized as:

$$y(t+1) = y(t) + v\frac{(y(t) - \text{yts}(t))(\text{ypo}(t) - y(t))}{\text{ypo}(t) - \text{yts}(t)} \text{ if } y(t) \geq \text{yts}(t), \tag{14}$$

$$\lim_{t\to\infty} y(t) = \text{ypo}(t) \text{ if } y(t_0) > \text{yts}(t) \text{ and}$$
$$\lim_{t\to\infty} y(t) = \text{yts}(t) \text{ if } y(t_0) = \text{yts}(t).$$

The second type of innovations, *innovation failures*, are those in which the condition involving the threshold condition is not met, i.e. where the relevant threshold value is not reached at the time the innovation enters the market. In this case, initial demand successively diminishes during the following steps until it converges to 0.

$$y(t+1) = y(t) + v\frac{y(t)\,(y(t) - \text{yts}(t))}{\text{yts}(t)} \text{ if } y(t) < \text{yts}(t) \tag{15}$$

$$\lim_{t\to\infty} y(t) = 0 \text{ if } y(t_0) < \text{yts}(t).$$ [124]

Both innovations and imitations are crucial features of environments characterized by competition. In our model we assume that successful imitators can attract a certain share of the demand potential created by an innovator. Technically, this means that intertemporal increases of demand (based on the diffusion dynamics described above) are equally shared among innovators and imitators of a specific product if y(t) < ypo(t).

Another remarkable characteristic of the diffusion of innovation is that it replaces conventional products to a certain extent. This can be thought of as a form of creative destruction

[124] An intermediate outcome emerges if $y(t_0)$ = yts(t). In this case, the demand approaches the threshold value yts(t).

which leads to a situation in which innovators grow at the expense of other firms that lose part of the current demand. On the other hand, it is possible that innovations are not directly competing with conventional products and create additional demand. These considerations are taken up in our model by introducing a substitution parameter *su* that measures the degree by which conventional products are replaced by innovative products.

Referring again to the diffusion dynamics, we can formalize the growth of demand due to innovative products for a certain sector (where W denotes the absolute growth of demand and k={1..r} are the innovations in the sector under consideration):

$$W(t+1) = \sum_{k=1}^{r} (y_k(t+1) - y_k(t)). \tag{16}$$

But, as new demand substitutes for conventional demand to a certain degree, we can define, with the help of the substitution factor, an overall growth rate of demand. Setting $Y(t) = \sum_{k=1}^{s} yk(t)$ (s denoting the number of agents in a given sector) it follows:

$$\frac{Y(t+1) - Y(t)}{Y(t)} = \frac{(1 - su)\, W(t+1)}{Y(t)}. \tag{17}$$

For the extreme cases of the substitution factor, this means:

- if *su* = 1, all additional demand of innovations replaces current demand. There are no net growth effects,
- if *su* = 0, all additional demand from innovations is added to the existing demand.

For intermediate values innovation can be thought of as showing both characteristics: it replaces some part of conventional demand and adds a new component to it.[125]

All the aspects considered so far are of crucial importance for the financial performance of the firm. This is caused by the fact that demand for its products generates a feedback to the

[125] In order to achieve this sectoral outcome, the demand facing the individual firm is rescaled by a scaling factor: $sf(t) = \frac{Y(t) + (1 - su)\, W(t+1)}{Y(t) + W(t+1)}$.

financial performance of the firm. In particular, we introduce the following features in our modelling framework:

- for each product, there exists a linear return and a linear cost function which depend on demand as described by the difference equations above;
- there is an additional cost component associated with innovation projects (this is a model parameter that can be varied);
- profit is turnover originating from sales of innovative and conventional products (depending on the return function) minus variable and fixed cost.

Financial resources are updated according to profits (losses) of the current period. The financial performance of the firm can finally give rise to another reason a product disappears from the market. It is assumed that a firm stops producing a certain product once the revenues of a product no longer cover production costs. This happens when the demand for such a conventional product diminishes, especially by the substitution mechanism mentioned above.

The *entry* of new firm agents is modelled probabilistically: In each time step and for each production sector, a new firm agent is created with a probability that depends linearly on the sector-specific indicator of competition intensity and on the amount of public subsidies for new entrants. Whereas the indicator of the competition intensity is subject to an exogenous linear dynamic, the amount of public subsidies is a model parameter. An entrant firm does not sell any conventional products; it always starts with an attempt to create an innovative product (either individually or cooperatively). The behavioral type of an entrant firm agent is set probabilistically as well; the probability distribution corresponds to the shares of the behavioral types given at the beginning of the simulation when the initial firm agent population was created.

If the financial resources of a firm agent fall beyond zero (meaning the agent runs into debt), the agent *exits* the market. This can happen in the course of an innovation or imitation project if the actual profit (gained by conventional products and innovative products that already have been put on the market before) falls behind the expected profit (which the agent calculates on the basis of the profit in the previous time steps), or if the actual development duration and, consequently, the actual development costs exceed the expected duration or costs, respectively.

To sum up: This modelling of the diffusion process is a combination of agent-based and parametrized components. The agent-based component determines the point in time as well as the type of the occurring novelty. Furthermore, according to the performance and the knowledge endowment of the innovating agents, a dynamic market potential as well as critical mass is defined for every product. Based on that, the distribution of the first mover advantage between novelty creating agents is determined exogenously. What is beyond the scope of this analysis is a fully fledged modelling of the adopters of new products, in that especially the velocity of market potential exhaustion and the amount of substituting old products by new one are derived from an explicit modelling of adopter agents. These effects are parametrized in the diffusion dynamics presented here.

Both aspects of innovation, namely creation and destruction, can be found at the level of diffusion as well. This includes, on the one hand, the creation of additional demand by innovative products. On the other hand, there is an inherent dynamics of demand destruction for conventional products which is particularly captured by the substitution factor. Additionally, from the point of view of an individual firm, innovation-induced destruction emerges if a part of its demand is competed away by imitators as well as in the form of a decision to abandon a product delivery once it is no longer viable in terms of covering the production costs.

4.5.4. Simulation results

4.5.4.1. Exemplary analysis of a singular run

To explore the emergence of sectoral growth and the impact of heterogeneity of firm agents, we show results of a simulation run with four production sectors and three types of firms being different in behavioural terms. Each production sector comprises 23 firm agents, among which seven belong to the conservative behavioral type, five to the cautious and eleven to the experimental type.[126] Tab. 11 summarizes the values of the most important model parameters for the standard configuration.

[126] These shares for the behavioral types are taken from findings of an empirical investigation in the region of Northern Hesse in Germany (Beckenbach et al. 2009).

Tab. 11: Important model parameter settings

Parameter	Value	Parameter	Value
Mean duration of innovation	6	Cooperation threshold (*ct*)	.5
Mean duration of imitation	3	Absorptive capacity (*ac*)	1
Cost of innovation per time step	.125	Sensitivity of knowledge transfer probability w.r.t. trust (*se*)	1
Cost of imitation per time step	.0625	Initial value of trust	.75*
Exploration drive ($w0$)	.15; .2; .25*	Trust increment	.1
Risk acceptance (α)	2; 2.5; 3*	Trust decrement	.2
Weight of profit aspiration (w_1)	0.04*		
Weight of market share asp.(w_2)[127]	0.05; 0.04; 0.06*		
Mean flexibility of adaptation (φ)[128]	.25	Trust threshold	.5
Propensity to cooperate (χ)	.7; 1; 1.3*	Substitution factor (*su*)	.75
Weights of components of coop. force (*ifb*, *iff*)	.25	Subsidies for an entrant firm (*sc*)	.5

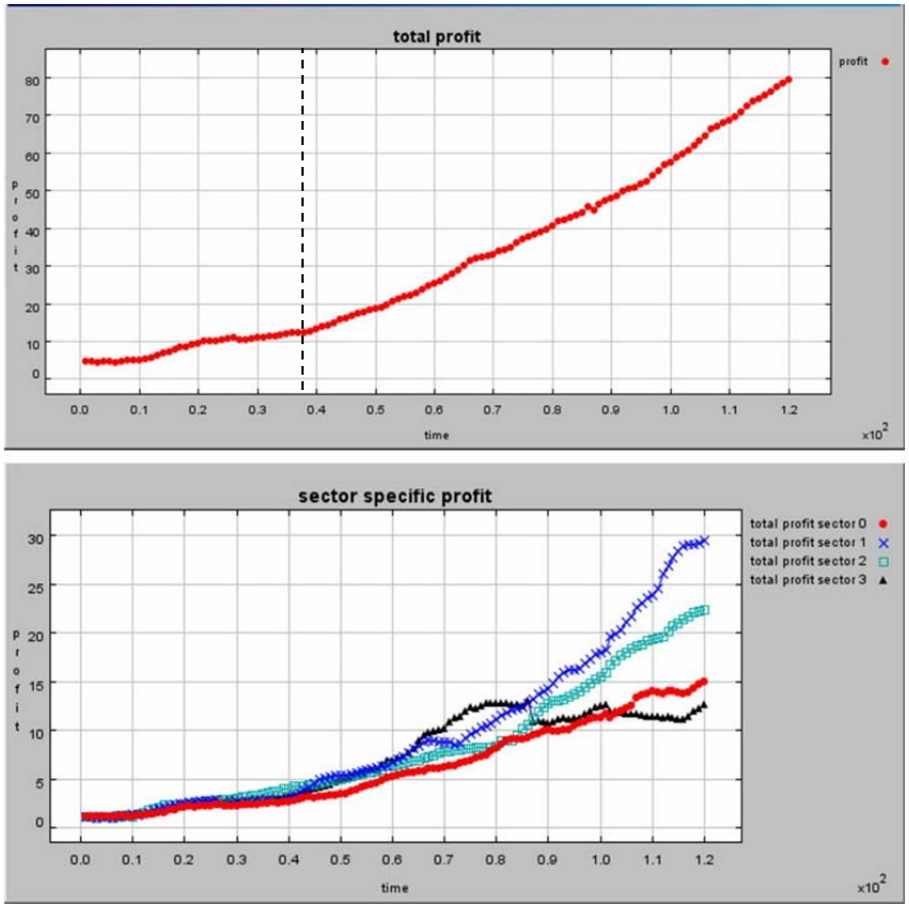
If there are three values separated by semicolons in the „value" column, these values correspond to the three behavioral firm types (in the order conservative, cautious, experimental) according to the empirical findings mentioned above. The values are either based on these empirical findings (*) or on estimates

According to the architecture of the simulation model, the economic outcome can be analyzed on different levels of aggregation. At the highest level of aggregation (the ‚national' level) is aggregated net value (i.e. the profits over all sectors) over time. The parameter settings summarized in Table 1 are tantamount to an optimistic scenario, leading to an continuous increase of net production in 120 time steps (30 years) (Fig. 36; up). Below this aggregated level there is an uneven development of the different sectors due to their internal dynamics in terms of novelty creation (Fig. 36; down). As regards the action modes, it can be observed that, after the transient phase (up to about t = 38; cf. dotted lines in Fig. 36 (up) and Fig. 37), an inverse cyclical development of innovation and imitation frequencies can be observed, indicating that phases dominated by innovation and phases dominated by imitation alternate. In this quasiregular state in terms of action modes, the growth of the net value increases significantly.

[127] [In the original article, the index of this parameter had an incorrect value.]

[128] [In the original article, the capital letter was given incorrectly.]

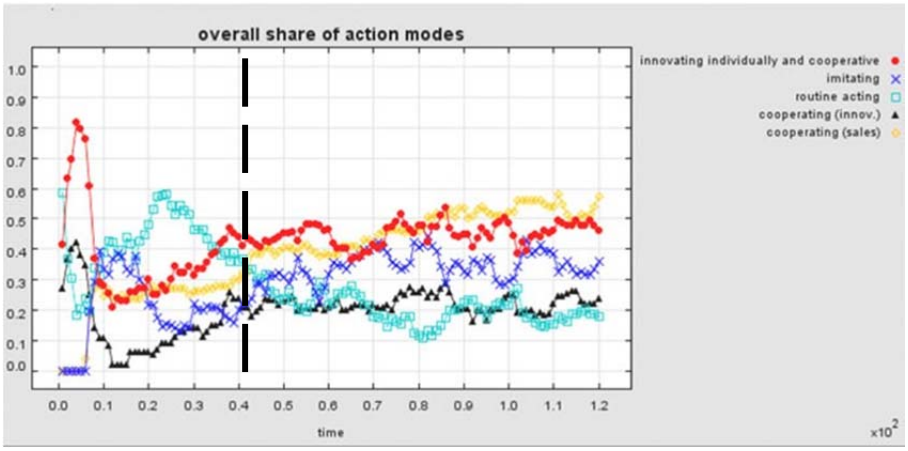
Fig. 36: Total profit (*up*) and sector specific profits (*down*)



In the given simulation framework, the generation of new knowledge is not an exogenous element; it is strongly tied to the innovation process. According to the slowly increasing share of innovation activities (Fig. 37), the societal endowment with knowledge increases moderately. **Fig. 38** (up) shows this moderate increase of the overall level of knowledge in terms of the average number of domains, about which the agents have knowledge. Disaggregating this indicator to the level of sectors manifests different sectoral knowledge dynamics (**Fig. 38**; down). The impression that novelty creation produces increasing heterogeneity in terms of knowledge is backed by further disaggregating the societal knowledge stock in different domains (Fig. 39; up) and by taking into consideration distinct modes of knowledge acquisition (Fig. 39; down). Disaggregating the knowledge stock into agent-specific components (sum total of individually disposable knowledge components) and tracing these components in the course of time shows, for many agents, an increase of knowledge and, for some agents, a decrease resulting in a persistent heterogeneity between individuals (Fig. 40; left); the lighter the grey, the higher the knowledge – white representing ‚no agent existing‘,

i.e. exit and late entry). Further disaggregation into the time-dependent knowledge of an arbitrarily chosen agent (Fig. 40; right) illustrates that the domain-specific knowledge is discontinuous, depending on forgetting and devaluating the existing knowledge (white representing areas of knowledge).

Fig. 37: Shares of action modes over time



The shares of innovating, imitating and routine acting agents sum up to 1 as each agent acts in each time step in exactly one of these three modes (they are mutually exclusive). However, agents participating in innovation cooperation form a subset of innovating agents. Hence, their share is never greater than the share of innovating agents. The participation in a sales cooperation is compatible with any action mode, so the share of agents participating in such a cooperation is independent of the shares of other action modes

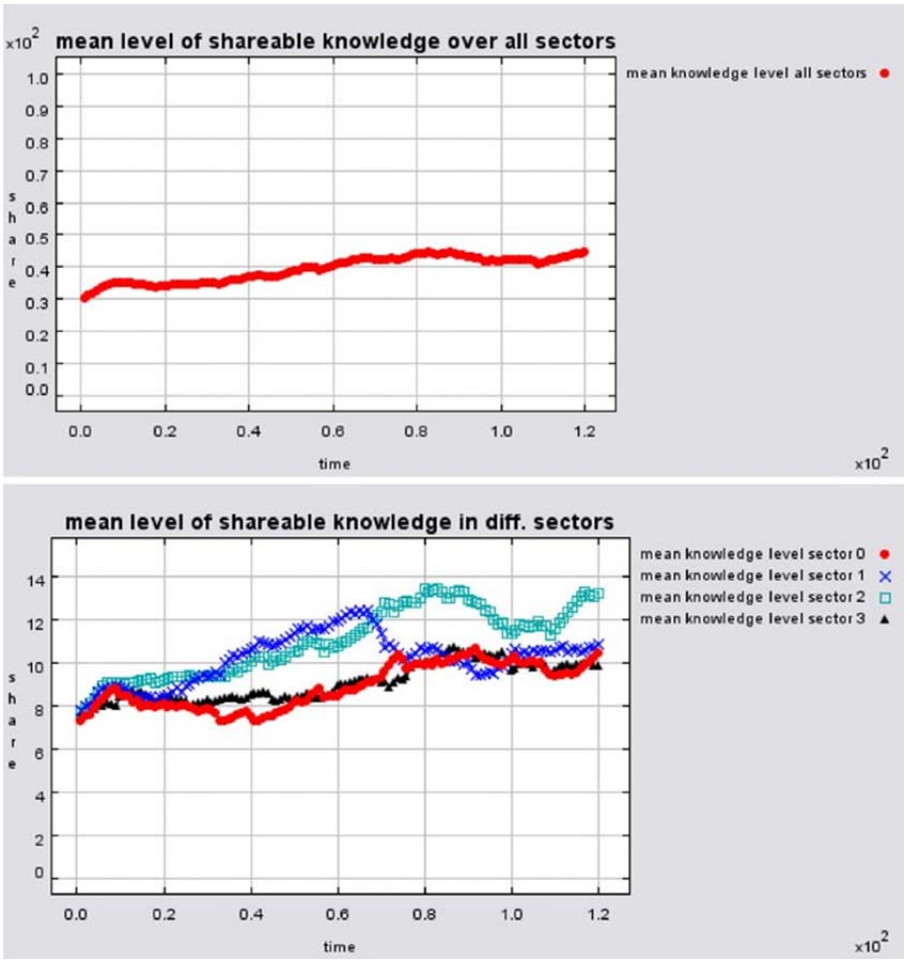
4.5.4.2. Sensitivity analysis

It has been argued above that, from the perspective of innovation analysis, the economic activities have a dual nature: on one side they tend to replicate and, on the other side, there is an endogenous mechanism for disturbing this well-established state of affairs. Correspondingly, the innovation has two sides: a creative and a destructive one. Breaking routines, devaluating knowledge, replacing conventional demand and the exit of firms are different dimensions of the destructive side of innovation.

To demonstrate this two-sided effect of innovation, we select the parameter determining the replacement effect for conventional demand (*su*). In the first row of Fig. 41, it is shown how the outcome of the innovation dynamics in terms of total profit, frequency of innovation

activities and the number of exits is changing if this substitution parameter is increased.[129] In all these outcome indicators, the destructive effect given by an increased ease to replace conventional demand (high values of *su*) can be verified. Due to intensified competition, the constraints for innovation become more critical and the risk of exit increases.

Fig. 38: Mean level of sharable knowledge over time



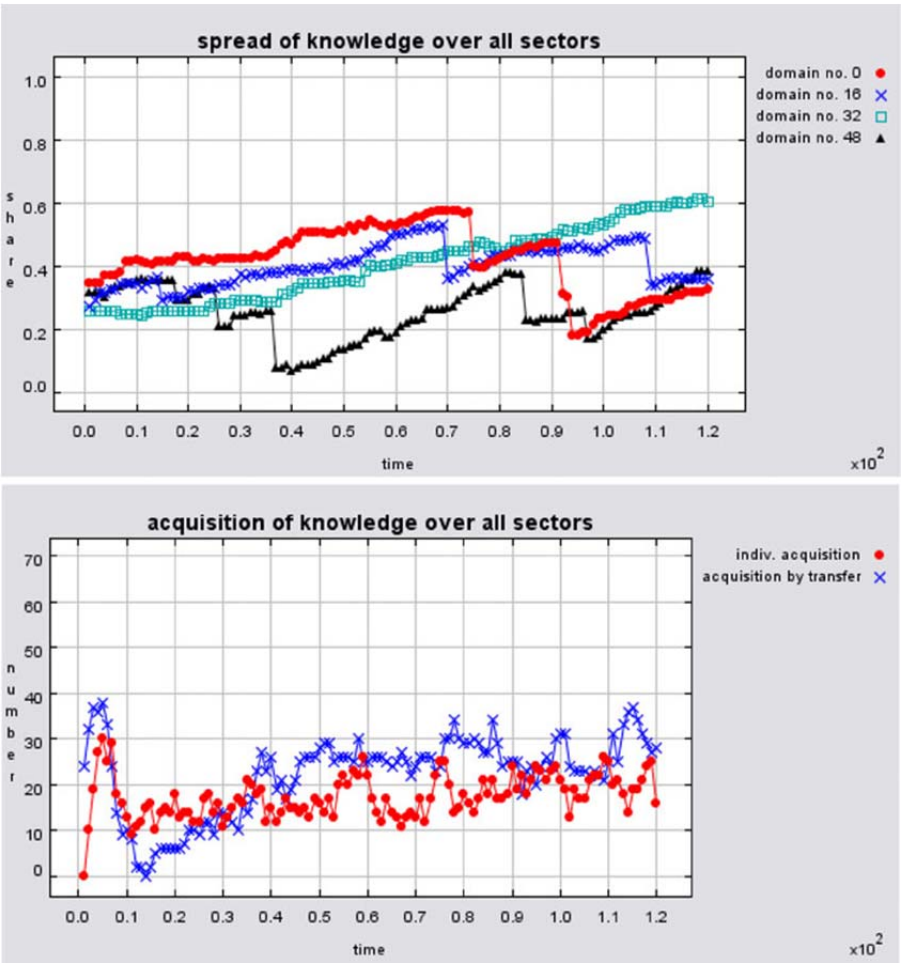
In the second row of Fig. 41, it is depicted to what degree an increase in the aspiration adaptability (more precisely, the flexibility to adapt the aspiration level related to the different goals symbolized by φ) can partly compensate for this destructive effect as regards the outcome indicators.[130] Although the frequency of innovation can be increased by increasing

[129] Values in Fig. 41 are cumulated average values of the respective indicators at the end of the simulation run.

[130] For each combination of values for these parameters, a Monte Carlo simulation with 16 runs with different seed values for the random number generator has been run. The darker the grey, the higher the respective indicator.

this adaptability, the positive overall effect on total profit is moderate due to demand constraints (at high levels of *su*). The results regarding total profit are not systematically influenced by the impact of φ. Profits per innovation project, however, tend to be lower if φ is increased: innovators tackle more albeit less profitable innovation projects. Although the substitution parameter itself is positively correlated with the frequency of exits the adaptability has almost no influence on the former.

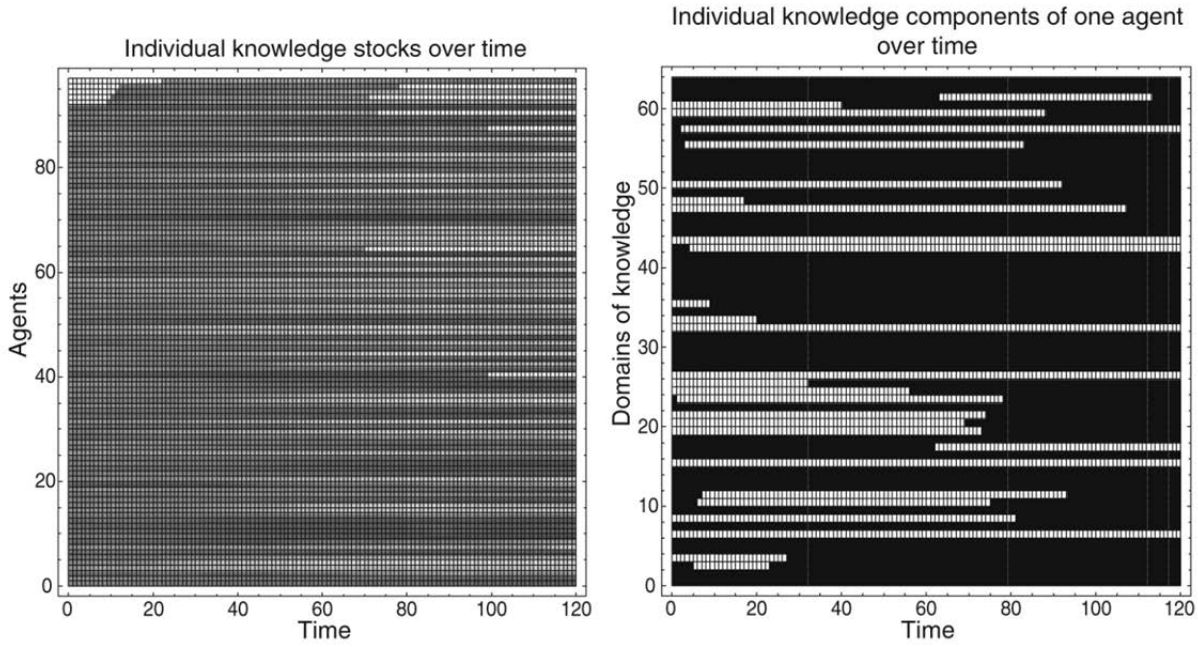
Fig. 39: Distribution and acquisition of sharable knowledge over time



Looking at the third row of Fig. 41, one can conclude that a compensation for creative demand destruction is more likely, if the exploration drive (w_0) is increased: for every level of *su*, an increase in this drive to innovate is tantamount to an increase in the number of innovations. This increase of innovation frequency is sufficient for increasing the total profit for low and medium range levels of *su*. But in a more competitive environment (high values of *su*), innovation failure is more likely and cannot be offset by increasing exploratory activities (high w_0). In this case, the number of exits is not significantly reduced if the exploration drive

is increased because the impact of competitive pressures (high level of *su*) becomes more important.

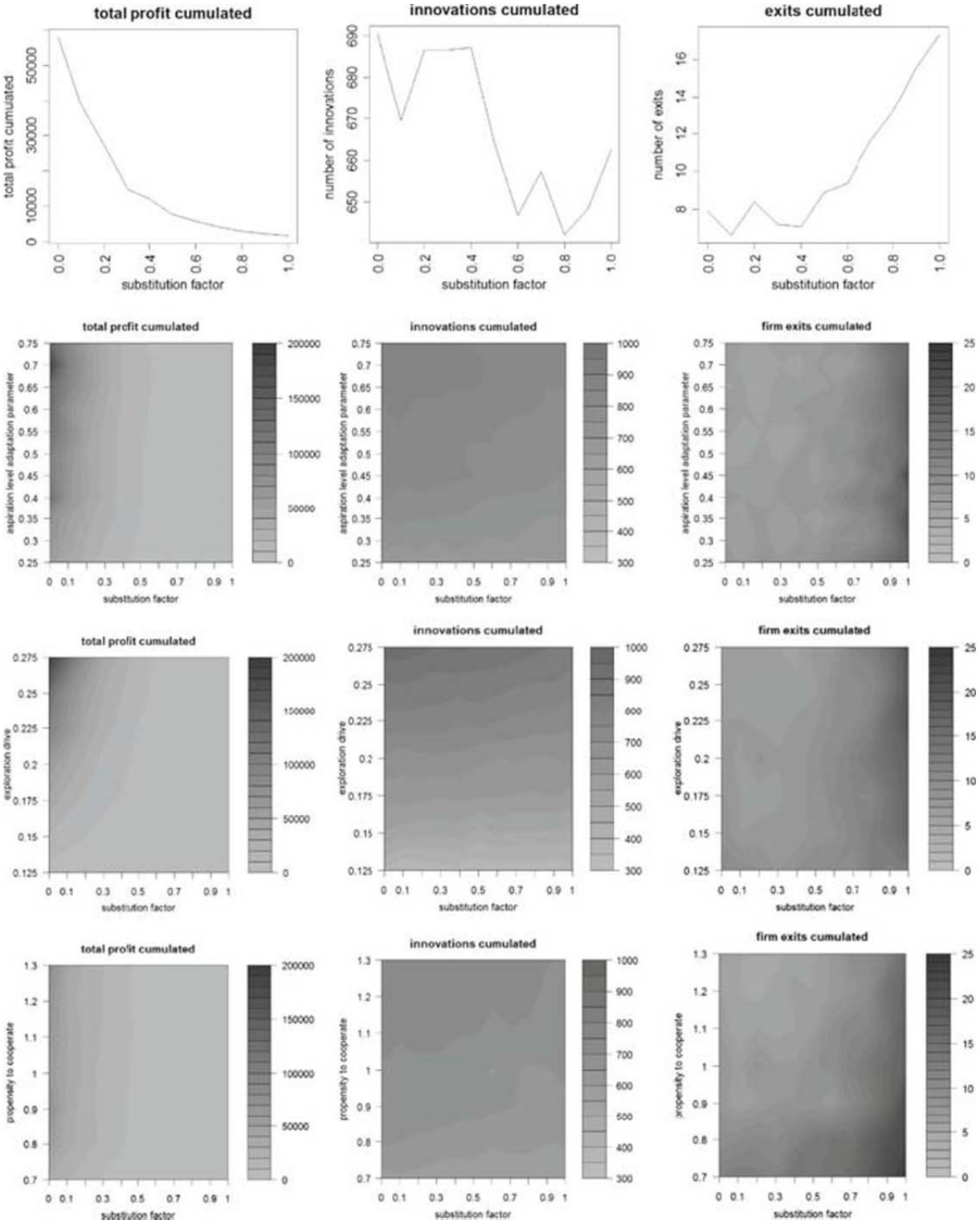
Fig. 40: Individual level of sharable knowledge over time



Finally, in the fourth line of Fig. 41, it is shown what happens if an increase in innovation induced substitution of demand is accompanied by an increase of the propensity to pursue cooperative innovation (χ). Not surprisingly, the frequency of innovation is increasing due to the facilitating effect of such a cooperation. But, as in the case of increased adaptability, the amount of additional innovation activities is not sufficient to have a significant effect on total profits. Finally, a higher number of exits is associated with a low level of cooperation drive (low values of χ) and more intense competition (high values of *su*). In this regard, a higher propensity towards cooperative innovations seems to safeguard against exits.

To sum up: if considered in isolation, behavioral parameters favoring innovation are appropriate for compensating the effect of creative demand destruction only in a limited way. For medium and high range values of the substitution parameter, a compensating boost of innovation dynamics is required which can only be achieved by an extraordinary combination of specific behavioral parameters changes. Hence, the normal state of affairs seems to be that innovations have a creative and destructive effect at the same time, the balancing of which determine the dynamics of sectoral growth.

Fig. 41: Sensitivity analysis for the substitution parameter and various behavioral parameters



4.5.5. Conclusions

One of the aims of the model suggested here is to specify the link between novelty creation and sectoral growth by including the internal trigger conditions for this type of economic activity. Explaining these trigger conditions necessitates a behavioral foundation for agents pursuing such a novelty creation. Not only situations favourable for the occurrence of novelty creating activities but also the particular form they come about are within the realm of such an explanation. Hence, a population of agents differing in their propensity to activate different modes of action can be derived and focused as the main explanans for the overall growth. It has been shown that such a behavioral foundation can draw upon the contributions made by the Carnegie School.

But to consider single agents triggering novelty creating activities is only the starting point for assessing the corresponding growth effect. The results of these activities have to be accepted by the demand and, if so, they are feeding an interactive diffusion process at the sectoral level. As a result of the different qualitative nature and of the different scale of the dynamics on these levels, a multi-level approach is an appropriate method for analyzing the sectoral growth dynamics.

A common denominator of these spreading effects of novelty creation is its twofold nature: apart from being ‚creative' they are also ‚destructive' in that established behaviors, artefacts and processes are overcome or degraded. On the behavioral level, established routines are broken, on the sectoral level conventional processes and products are replaced. Against this background, another aim of the model suggested here was to show how the creative and the destructive components of novelty creation are constituted on the different levels and how the balancing of these components creates an overall (growth) effect.

Finally, at least some of the well-known stylized facts of novelty creating processes can be reproduced by the suggested model:

- agents are not homogenized in the course of time; rather their heterogeneity in terms of knowledge and action modes persist (Dawid 2006, p. 1241);
- the share of innovating agents is an emerging property and corresponds roughly to the statistical data (Rammer 2006);

- after the transient phase, there is a cyclical pattern correlating innovation and imitation inversely signifying that there are succeeding phases dominated by (radical) market innovation and phases with (incremental) imitation (Utterback 1996, pp. 79).

Further elaborating on a behaviorally enriched evolutionary growth model seems to be a promising path for future scientific research. Deepening the behavioral foundations by taking into account the composed nature of (at least medium and large sized) firms, endogenizing the demand side of the diffusion dynamics and specifying the technology-driven sectoral input/output coefficients as a basis for integrating the interdependencies between sectors will be some areas this research will have to tackle.

5. Zusammenfassung und weitere Forschungsfragen

Thorstein Veblen und Joseph Schumpeter haben mit der Betonung der Relevanz der Analyse des Innovationshandelns von Akteuren eine grundlegende Ausrichtung ökonomischer Forschung hin zu einer Alternative zum standardökonomischen Ansatz vorgegeben. Diese Ausrichtung findet sich im Kern bereits schon bei Smith und ist eine wesentliche Grundlage für ein besseres Verständnis realer wirtschaftlicher Prozesse. Jedoch ist festzustellen, dass in der Innovationsökonomik als der generisch mit dem Gegenstandsbereich befassten wissenschaftlichen Disziplin zwar der unabkömmliche empirische und wirtschaftliche Bezug hergestellt wird, eine Orientierung an der Entwicklung eines derartigen alternativen Theorierahmens aber weitestgehend ausbleibt. Dies korrespondiert mit der Ausrichtung der Fragestellung der empirischen Innovationsökonomik, die sich weniger auf Akteurskonzepte denn auf (teilweise auch problematische) Standardindikatoren bezieht. So führt auch Cohen (2010) die von ihm identifizierten Probleme der Falsifikation der Ergebnisse der empirischen Innovationsökonomik auf die fehlende theoretische Einbettung zurück.

Die Evolutionsökonomik, die sich unmittelbar auf Veblen und Schumpeter bezieht, bietet mit ihrer Fokussierung auf den durch Innovationsprozesse getriebenen wirtschaftlichen Wandel einen Rahmen für ein entsprechendes alternatives Forschungsprogramm. Allerdings lässt sich feststellen, dass die akteursbasierte Analyse von Innovationsprozessen in den evolutionsökonomischen Diskussionen zwar angesprochen und von einigen Autoren auch prominent vertreten wird, aber schon die in Abschnitt 2.2.2 der vorliegenden Arbeit vorgestellte kurze bibliometrische Analyse verweist darauf, dass die Entwicklung eines Akteurskonzeptes noch aussteht. Dies ist insoweit verwunderlich, als mit dem die evolutionsökonomische Diskussion prägenden Werk von Nelson und Winter (1982) früh Bezug auf die SCP („Simon/Carnegie Perspective“; Dosi 2004, 213) genommen wurde. Nelson und Winter eröffneten damit den Zugang zu einem Akteurskonzept, welches sowohl Einzelindividuen als auch Unternehmen betrachtet und zudem das Innovationshandeln als einen zentralen Aspekt thematisiert. Die kurze bibliometrische Analyse macht dabei zum einen deutlich, dass es an der empirischen Umsetzung der Fragestellung mangelt, und zum anderen, dass nur relativ wenige Autoren die Potentiale nutzen, die die Verwendung einer spezifischen Methode der Computersimulation (Multi-Agentensystem) bietet.

Ziel der vorliegenden Arbeit war es vor diesem Hintergrund, einen Beitrag zu einer (empirisch) gehaltvollen Mikrofundierung des Innovationsgeschehens im Rahmen einer evolutorischen Perspektive auf den wirtschaftlichen Wandel zu leisten. Der verhaltensbezogene Schwerpunkt der vorliegenden Arbeit ist dabei, in unterschiedlichem Ausmaß, auf das Akteurs- und Innovationsmodell der SCP ausgerichtet und ergänzt, spezifiziert und erweitert dieses u.a. um vertiefende Befunde der Kreativitäts- und Kognitionsforschung bzw. der Psychologie und der Vertrauensforschung sowie auch der modernen Innovationsforschung. Die Arbeit nimmt dabei auch Bezug auf einen gesellschaftlich und ökonomisch relevanten Gegenstandsbereich der Innovation, die Umweltinnovation. Sie ist sowohl konzeptionell als auch empirisch ausgerichtet, zudem findet die Methode der Computersimulation in Form zweier Multi-Agentensysteme Anwendung.

Die vorliegende Arbeit beinhaltet, neben einer Einleitung und einer ausführlichen Darstellung des theoretischen Hintergrunds, fünf Artikel. Diese haben unterschiedliche Aspekte von Innovationsprozessen zum Thema, deren Kern aber das von Pfadabhängigkeiten, Rückkoppelungen und Umfeldinterdependenzen geprägte Innovationsentscheiden und -handeln von mit spezifischen Merkmalen ausgestatteten, prozedural rationalen Akteuren ist. Analyseebenen sind sowohl Einzelindividuen als auch Unternehmen sowie sektorale Prozesse. Die fünf Artikel nehmen hierzu Aspekte des Werkes der SCP auf und passen diese an den jeweils vorliegenden Untersuchungsgegenstand und auch an die verwendete Methode an. Die Themenschwerpunkte der fünf Artikel und der entsprechende Verlauf der Arbeit lassen sich folgendermaßen charakterisieren: Es erfolgt *erstens* ein Beitrag zu einer erweiterten Perspektive und konzeptionellen Verdichtung des Problemlösungskonzeptes von Newell/Simon (1972). Mit Blick auf Inventions- und Innovationsprozesse werden auch Befunde der Kreativitäts- bzw. der Kognitionsforschung berücksichtigt. *Zweitens* wird sich konzeptionell mit der Operationalisierbarkeit von Inventions- und Innovationsprozessen im Hinblick auf empirische Erhebungen befasst. Dies erfolgt unter Bezugnahme auf die ‚Theory of Planned Behavior' (Ajzen 1991; s. auch Fishbein/Ajzen 2010) und die SCP sowie unter Berücksichtigung des zeit- und pfadabhängigen Charakters des Innovationsgeschehens. *Drittens* erfolgt exemplarisch die Überführung einer akteursbasierten Perspektive in einen konkreten empirischen Untersuchungsgegenstand, eine spezifische Art von Umweltinnovation. Hierbei steht das Initiationskonzept der SCP im Fokus, wobei die gewählte statistische Methode, die Strukturglei-

chungsmodellierung, eine komplexere Erfassung von Kausalitäten ermöglicht, als es mit den üblichen Methoden der Ökonomik möglich ist. *Viertens* werden die Mikroprozesse der Dynamik von Wissensaustausch und Vertrauen in Forschungs- und Entwicklungskooperationen untersucht. Hierzu wird ein Modell entwickelt, welches entsprechende Verhaltensaspekte, etwa absorptive Kapazität und Reziprozität, erfasst. Um deren Zusammenwirken zu analysieren, erfolgt eine Überführung des theoretischen Modells in ein Differenzengleichungssystem und die Gleichungen werden in eine Computersimulation, ein Multi-Agentensystem, überführt. In diesem Rahmen wird eine systematische Analyse der Wirkung unterschiedlicher Akteursausstattungen und Gruppenzusammensetzungen durchgeführt, welche zeigt, wie selbst bei einer niedrigen Anzahl von Akteuren die Ergebnisse sehr stark differieren können. *Fünftens* schließlich wird eine zeitliche und sachliche Erweiterung des Innovationsmodells der SCP vorgenommen und wiederum in ein Computermodell umgesetzt, in dessen Zentrum die Entscheidungen, Handlungsmodi und Interaktionen von heterogenen, prozedural rationalen Akteuren sowie die hieraus resultierenden emergenten und auch rückwirkenden Effekte des wirtschaftlichen Wandels, hier der sektoralen Entwicklung, stehen.

Als zusammenfassendes Ergebnis lässt sich im Allgemeinen festhalten, dass Innovationen als hochprekäre Prozesse anzusehen sind, welche auf einer Verbindung von spezifischen Akteursmerkmalen, Akteurskonstellationen und Umfeldbedingungen beruhen, Iterationsschleifen unterliegen (u.a. durch Lernen, Rückkoppelungen und den Aufbau von Vertrauen) und Teil eines umfassenderen Handlungs- sowie (im Falle von Unternehmen) Organisationskontextes sind. Das Akteurshandeln und die Interaktion von Akteuren sind dabei Ausgangspunkt für Emergenzen auf der Meso- und der Makroebene.

Die Ergebnisse der Analysen in den fünf Artikeln zeigen im Speziellen, dass der Ansatz der SCP eine geeignete theoretische Grundlage zur Erfassung einer prozessorientierten Mikrofundierung des Gegenstandsbereiches der Innovation darstellt und – bei geeigneter Ergänzung und Adaption an den jeweiligen Erkenntnisgegenstand – eine differenzierte Betrachtung unterschiedlicher Arten von Innovationsprozessen und deren akteursbasierter Grundlagen sowohl auf der individuellen Ebene als auch auf Ebene von Unternehmen ermöglicht. Dabei wird auch deutlich, dass die SCP mit dem Initiationsmodell einen zusätzlichen Aspekt in die Diskussion einbringt, welcher bislang wenig Aufmerksamkeit fand, jedoch konstitutiv für eine ökonomische Perspektive ist: die Analyse der Bestimmungsgrößen (und des Prozesses) der

Entscheidung zur Innovation. Denn auch wenn das Verständnis der Prozesse bzw. der Determinanten der Erstellung, Umsetzung und Diffusion von Innovationen von grundlegender Bedeutung ist, ist letztendlich die Frage, warum und unter welchen Umständen Akteure sich für Innovationen entscheiden, ein zentraler Kernbereich einer ökonomischen Betrachtung.[131]

In diesem Zusammenhang lassen sich mindestens zwei Aspekte identifizieren, welche darauf verweisen, dass eine stärkere Berücksichtigung der Grundlagen der Entscheidung zur Innovation sowie der in der vorliegenden Arbeit im Sinne der SCP als Problemlösungsprozess gefassten Innovationsgenese von großer Bedeutung ist und Bedarf an weiterführender Forschung besteht.

So kann eine stärkere Fokussierung auf den Entscheidungs- und Entstehungsprozess e*rstens* dem in der Evolutionsökonomik diskutierten Problem begegnen, dass die Resultate von Innovationshandlungen per se nicht vorhersagbar sind. Denn insofern das Innovationsgeschehen im Sinne der SCP und der vorliegenden Arbeit gefasst wird, ist die Innovationshandlung als ein intendierter, deliberativer Prozess zu verstehen, dessen Ausgangspunkt die Entscheidung für diesen Prozess ist. Diese Entscheidung ist ein validierbarer Gegenstandsbereich, der einen Korridor für die Richtung der Innovation impliziert und damit auch die Identifikation von relevanten Ressourcen und Rahmenbedingungen sowie die wissenschaftliche Auseinandersetzung hiermit erlaubt. Zu analysieren wäre beispielsweise, welche internen und externen Einflussgrößen und Prozesse die Genese und Ausprägung neuer Ziele und unter Umständen auch die Degradierung vorhandener Ziele hervorrufen und inwieweit hierdurch Innovationsprozesse induziert werden. Entsprechendes ist auch in Bezug auf die Auseinandersetzung mit den Problemlösungsprozessen, die der Innovationserstellung zu Grunde liegen, zu konstatieren: Es können u.a. relevante Fähigkeiten, Ressourcen, vertrauensbezogene Akteurseigenschaften, Gruppenzusammensetzungen und Umfeldbedingungen identifiziert werden, welche als Gegenstandsbereiche wissenschaftlicher Forschung erfasst werden können. Somit finden sich hinreichend Ansatzpunkte zur Auseinandersetzung mit der Mikrofundierung von Innovationen, auch wenn das konkrete Ergebnis von Innovationsprozessen, je nach Neu-

[131] Auf einer eher allgemeineren Ebene mag hieraus auch im Sinne von Gavetti et al. (2007) der Schluss gezogen werden, dass es an der Zeit ist, die entscheidungstheoretischen Grundlagen der SCP wieder in den Fokus zu rücken.

heitsgrad, ex ante nicht oder nur partiell antizipiert werden kann und/oder ex post auch nichtintendierte Resultate identifiziert werden können.

Eine derartige Auseinandersetzung mit den Grundlagen der Entscheidung zur Innovation ist *zweitens* auch dann von Relevanz, wenn Vorschläge für die Ausgestaltung von Innovationspolitiken formuliert werden sollen. Letztendlich haben Innovationspolitiken das Ziel, Akteure zur Durchführung von Innovationen, und dabei zumeist zu einer bestimmten Art von Innovation, zu motivieren; d.h. entsprechende Politiken zielen im Kern darauf ab, eine Innovationsentscheidung zu induzieren. Deshalb liegt es nahe, dass eine vertiefende Auseinandersetzung mit der Frage der Initiation von Innovation und den Innovationsprozessen für die Ausgestaltung von wirtschaftspolitischen Maßnahmen von Bedeutung ist.

Der in der vorliegenden Arbeit unter Bezugnahme auf die SCP dargestellte akteursbasierte Ansatz bietet noch eine Reihe von Aspekten für weiterführende Forschungen; vor dem Hintergrund des aktuellen Diskussionsstandes der Ökonomik bietet es sich dabei an, das Beispiel der SCP aufzunehmen und, soweit möglich und sinnvoll, eine interdisziplinäre Perspektive einzunehmen. Entsprechende Forschungen könnten u.a. folgende Aspekte beinhalten:

- Weiterentwicklung des Konzeptes der prozeduralen Rationalität bzw. des Innovationskonzeptes der SCP unter Einbeziehung entsprechender (neuerer) Erkenntnisse der Nachbardisziplinen und vertiefender Adaption an konkrete ökonomische Untersuchungsgegenstände. Hierbei könnte im Übrigen nicht nur an relevante Erkenntnisse der experimentellen Verhaltensökonomik angeknüpft werden, vielmehr bietet eine solche Akteursfundierung auch neue Ansatzpunkte für die Ausgestaltung von entsprechenden Experimenten.
- Anwendung des Konzeptes der prozeduralen Rationalität auf weitere Akteursgruppen wie etwa auf Konsumenten und Politikakteure. Hinsichtlich der ersten Akteursgruppe findet sich in der Marketingforschung eine vertiefende Auseinandersetzung mit Konzepten der Psychologie oder auch der ‚Theory of Planned Behavior' von Fishbein/Ajzen. Die Untersuchung der prozeduralen Rationalität in Bezug auf Politikakteure wäre ein relativ neuer und zumindest derzeit keiner spezifischen Disziplin zuzuordnender Gegenstandsbereich.
- Vertiefende Analyse der für das Innovationsgeschehen relevanten Eigenlogiken und Spezifika von Subelementen von Entitäten mit multiplen Einheiten (wie Unternehmen). Die SCP bietet hierzu einige in der vorliegenden Arbeit nicht diskutierte und eher weniger auf das Innovationsgeschehen fokussierte Ansatzpunkte, welche sicherlich die Grundlage für eine

Weiterentwicklung bieten (s. entsprechend auch Simon 1986a, 17). Hier könnten u.a. entsprechende Befunde aus der Management- und Organisationsforschung aufgenommen werden.

- Intensivere Betrachtung der Interaktion und Interdependenz von Akteur und Akteursumfeld, insbesondere in Hinblick auf Vertrauensbildung, Normsetzung, Aktionspotentiale, Wettbewerb und die aus der Interaktion resultierenden wirtschaftlichen Prozesse. Hier bietet es sich ebenfalls an, auf die relevanten Nachbardisziplinen, u.a. auf die Soziologie (und hier insbesondere auch auf die Mikrosoziologie und Wirtschaftssoziologie) sowie z.B. auf die Sozialpsychologie Bezug zu nehmen.
- Systematische Erweiterung des Untersuchungsgegenstandes aus einer akteursbasierten Perspektive, zum einen z.B. auf Umweltinnovationen als spezifischen Innovationsarten, die vor dem Hintergrund des globalen Problems der Umweltunverträglichkeiten ökonomischen Handelns besonders relevant sind. Bezüge ergeben sich hierbei unmittelbar zur Umweltinnovationsforschung, wobei diese ein relativ junges Forschungsfeld darstellt; im Rahmen einer vertiefenden Auseinandersetzung mit dieser Themenstellung kann so auch zur Entwicklung dieses Forschungsfeldes beigetragen werden. Zum anderen können über den Innovationsgegenstand hinaus, und durchaus im Sinne von Schumpeter, weitere ökonomische Gegenstandsbereiche wie etwa Finanzmärkte, Rechtssyteme und Wirtschaftspolitiken in einen entsprechenden akteursfundierten Betrachtungsrahmen aufgenommen werden. Bezüge hierzu sind z.B. im Bereich der Wirtschaftspolitiken und (partiell) im Rahmen der Governanceforschung zu finden.

Mit Blick auf die Ausgestaltung weiterführender Forschungen soll nochmals auf die Relevanz der Erweiterung bzw. Vertiefung des methodischen Kanons hingewiesen werden: Für ein realistisches Akteurskonzept ist eine Orientierung am realen Entscheiden und Handeln und die Analyse der hieraus resultierenden Ergebnisse bzw. Marktprozesse sowie deren Rückwirkungen von grundlegender Bedeutung. Insofern ist zum einen eine deutlich stärkere originäre empirische Ausrichtung besonders wichtig; dies schließt auch die Verwendung von für die Ökonomik relativ neuen Methoden ein. Ein derartiges Vorgehen entspricht dabei dem Anliegen von Simon, welcher im Verlauf seines Forscherlebens immer wieder die Relevanz einer realitätsnahen empirischen Fundierung betont hat, so auch im folgenden Zitat:

„[…] the continuing progress of the economic theory of change and cycles requires massive empirical work at the level of the economic agents who make decisions – for example, the consumer and the firm. The dynamics of the economic system depends critically on just how economic agents go about making their decisions, and no way has been found for discovering how they do this that avoids direct inquiry into and observation of the processes. […] the required research is of a kind that is novel to most economists. It does not rest on statistical data derived from secondary sources, but calls for direct observation of human behavior in the market and in the firm.“ (Simon 1984, 52)

Da derartige empirische Analysen zeitlich, inhaltlich und vom Umfang her immer beschränkt sind, bietet die Übertragung der aus der Empirie gewonnenen Befunde in Computermodelle, d.h. in Multi-Agentensysteme, die Möglichkeit, Prozesse auf der Meso- und der Makroebene zu simulieren und somit mögliche Entwicklungspfade zu identifizieren. Insofern ist zum anderen eine verstärkte Anwendung von gehaltvollen, auf Basis empirischer Befunde kalibrierten Multi-Agentensystemen für weiterführende Forschungen von Bedeutung. Spiegelbildlich können Multi-Agentensysteme dazu beitragen, den konkreten Gegenstandsbereich einer empirischen Untersuchung ex ante zu evaluieren und somit zuzuspitzen.

Die hier skizzierten Forschungsfragen zu einer akteursbasierten Weiterentwicklung der Theoriebildung sind sicherlich nicht vollständig und werden partiell auch bereits verfolgt. Aber es wird vielleicht deutlich, dass ein derartiges, inhaltlich umfassendes, auch interdisziplinär ausgerichtetes und rückgekoppeltes Zusammenspiel von theoretischen Überlegungen, empirischen Beobachtungen und Computersimulationen gehaltvolle Beiträge zu einer akteursbasierten Innovationserklärung erwarten lässt. Ein solches Forschungsprogramm kann, soweit es sich auf den Innovationsgegenstand bezieht, zudem auch einen Beitrag zur Weiterentwicklung der Innovationsökonomik bzw. der Evolutionsökonomik leisten.

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7. Anhang

7.1. Anhang zu Abschnitt 2

Bibliometrische Analyse

Im Rahmen der vorliegenden bibliometrischen Analyse wurde untersucht, inwieweit sich die Publikationen der Evolutionsökonomik auf die SCP („Simon/Carnegie Perspective"; Dosi 2004, 213) im Allgemeinen bzw. auf das Innovationskonzept der SCP im Besonderen beziehen. Die bibliometrische Analyse wurde mittels der Rechercheoberfläche ‚EBSCOhost Discovery Service'[133] (EDS) vorgenommen.[134] EDS umfasst u.a. die Literaturdatenbanken ‚EconLit', ‚Web of Science' und ‚Social Science Open Access Repository' und ermöglicht somit eine umfassendere Suche, als es mittels einzelner Suchmaschinen bzw. Datenbanken möglich wäre. Insbesondere kann den Ergebniseinschränkungen der für bibliometrische Analysen häufiger verwendeten Literaturdatenbanken ‚EconLit'[135] und ‚Web of Science®'[136] zumindest partiell begegnet werden. Es ist allerdings kritisch anzumerken, dass EDS eine relativ aufwendige Nachbereitung und Kontrolle der Ergebnisse, z.B. in Bezug auf doppelte Nennungen, erfordert. Hilfreich ist hingegen, dass die Suche auf bestimmte Publikationsarten, u.a. auch auf Bücher und Konferenzbeiträge, festgelegt werden kann. Im Rahmen der vorliegenden Auswertungen wurde sich jedoch auf publizierte Artikel konzentriert, da zum einen beispielhafte Auswertungen ergaben, dass die Suche derzeit nur relativ wenige Bücher erfasst, und es zum anderen nicht ersichtlich ist, auf welche Konferenzen sich die Suche bezieht bzw. wie hier der Zugang realisiert wird.

Die Suchabfrage im Rahmen der vorliegenden bibliometrischen Analyse erfolgte mittels Stichwörtern, die mit Operatoren verbunden wurden, wobei, soweit sinnvoll möglich, eine

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[133] Siehe http://www.ebscohost.com/discovery/about; letzter Zugriff am 15.02.2013.

[134] Eine weitere Möglichkeit wäre es auch, die Suche über ‚Google Scholar' durchzuführen, denn diese Suchmaschine erfasst deutlich mehr Publikationen und hierbei insbesondere auch graue Literatur; sie bietet allerdings derzeit keine hinreichend differenzierte Abfragemöglichkeit.

[135] Die zunächst präferierte Datenbank EconLit wurde nicht ausgewählt, weil sich im Zuge erster Abfragen sehr niedrige Trefferquoten ergaben, welche laut Auskunft des Helpdesks von EBSCO (Mail vom 05.02.2013) darauf zurückzuführen sind, dass EconLit weniger Artikel in der Volltextsuchmöglichkeit erfasst als die nun ausgewählte Rechercheoberfläche (s. auch illustrierend Fn 138).

[136] ‚Web of Science®' (s. http://thomsonreuters.com/products_services/science/science_products/a-z/web_of_science/; letzter Zugriff am 15.02.2013) bietet keine Möglichkeit zur Volltextsuche.

Kurzform des Stichwortes gewählt wurde und mit einem Platzhalter mögliche alternative Endungen erfasst wurden. Die finale Abfrage erfolgte im April 2013 und erfasste Artikel, welche zwischen 1982, dem Jahr, in welchem das Werk von Nelson und Winter erschien, und 2011[137] publiziert wurden.

Bei der Gestaltung der Suchalgorithmen war dafür Sorge zu tragen, dass die der Evolutionsökonomik zuzurechnenden Fachbeiträge möglichst breit erfasst werden. Hierzu wurden *erstens* alle diejenigen Fachbeiträge in die Suche aufgenommen, die in Fachzeitschriften erschienen, welche für die Evolutionsökonomik relevant sind, und dabei im Volltext mindestens einmal die Begriffe ‚Evolutionary Economics' und/oder ‚Neo-Schumpeterian Economics' verwenden. Als relevante Fachzeitschriften wurden entsprechend Cantner/Hanusch (2002, 182) die folgenden in die Suchabfrage aufgenommen: ‚Journal of Evolutionary Economics'; ‚Journal of New Technology and Innovation'; ‚Industrial and Corporate Change' sowie ‚Strucural Change and Economic Dynamics'; weiterhin aufgenommen wurden die Fachzeitschriften, ‚Evolutionary and Institutional Economics Review'; ‚Journal of Economic Issues'; ‚Journal of Institutional Economics' sowie ‚Research Policy' (s. auch Silva/Teixeira 2009). Zusätzlich wurden *zweitens* alle Fachbeiträge aufgenommen, welche in den Schlüsselwörtern entweder die Begriffe ‚Evolutionary Economics' und/oder ‚Neo-Schumpeterian Economics' verwenden (unabhängig davon, in welcher Fachzeitschrift diese erschienen sind). Auf eine Volltextsuche nach entsprechenden Begriffen wurde an dieser Stelle verzichtet, da Volltextsuchen immer auch die Literaturverzeichnisse erfassen und somit z.B. ein Artikel, welcher einmal einen Fachbeitrag aus dem Journal of Evolutionary Economics zitiert, von dem Suchalgorithmus erfasst worden wäre. Mit der hier angewendeten Abfrage nach Zeitschriften und/oder Stichwörtern ist insofern zwar eine Restriktion verbunden, diese fokussiert jedoch die Ergebnisse stärker auf diejenigen Fachbeiträge, welche in einem engeren Sinne mit der Evolutionsökonomik verbunden sind.

[137] Die Bezugnahme auf das Jahr 2011 liegt darin begründet, dass der Zugang zu Volltexten, je nachdem in welche Zugänge die jeweiligen Universitätsbibliotheken investieren, häufig für 12 Monate ab Erscheinungsdatum gesperrt ist. Mit der Beschränkung auf 2011 sollte eine möglicherweise hieraus resultierende Verzerrung der Suchergebnisse vermieden werden.

Die entsprechende Abfrage (in der Tabelle 1 als ‚Basisalgorithmus 1' bezeichnet) ergab eine bereinigte Trefferquote von 5.064 Artikeln.[138] Geprüft wurde dann zunächst im Allgemeinen, inwieweit diese Artikel sich auf das Konzept der beschränkten Rationalität bzw. auf die SCP beziehen. Vor dem Hintergrund der vorliegenden Fragestellung wurden dann zum ‚Basisalgorithmus 1' Suchwörter hinzugenommen, welche einen Innovationszusammenhang kennzeichnen (in der Tabelle 1 als ‚Basisalgorithmus 2' bezeichnet). Somit konnten diejenigen Fachbeiträge identifiziert werden, welche sich auf das Themenfeld Innovation beziehen; dies waren bereinigt 1.834 Artikel. Aufbauend hierauf wurden dann jeweils Begriffe in den Suchalgorithmus aufgenommen, die den Ansatz der SCP charakterisieren. Die entsprechenden Algorithmen finden sich in Tabelle 1, wobei zunächst die Ergebnisse zum ‚Basisalgorithmus 1' und anschließend, grau schattiert, zum ‚Basisalgorithmus 2' dargestellt sind; hierzu werden jeweils die absoluten Werte und die Anteile erfasst. Deutlich wird, dass die Trefferquote umso stärker sinkt, je mehr oder je spezifischere Begrifflichkeiten der SCP vom Suchalgorithmus erfasst werden.

[138] Zum Vergleich: Dieselbe Abfrage ergab über ‚EconLit' 681 Treffer; über ‚Web of Science®' ist diese Abfrage wegen der fehlenden Möglichkeit zur Volltextsuche nicht ausführbar.

Algorithmen und Ergebnisse der bibliometrischen Analyse

	Algorithmus	Anzahl	In % von Anzahl Basis-algorithmus 1	In % von Anzahl Ba-sisalgorith-mus 2
Basisalgorithmus 1	((SO ("Journal of Economic Issues" OR "Journal of Evolutionary Economics" OR "Journal of Institutional Economics" OR "Evolution-ary and Institutional Economics Review" OR "Journal of New Technology and Innovation" OR "Structural Change and Economic Dynamics" OR "Industrial and Corporate Change" OR "Research Policy" OR "Economics of Innovation and New Technology") AND TX ("Evolutionary Economics" OR "Neo-Schumpeterian")) OR SU ("Evolutionary Economics" OR "Neo-Schumpeterian"))	5064	-	--
Basisalgorithmus 1 und beschränkte Rationalität	((SO ("Journal of Economic Issues" OR "Journal of Evolutionary Economics" OR "Journal of Institutional Economics" OR "Evolution-ary and Institutional Economics Review" OR "Journal of New Technology and Innovation" OR "Structural Change and Economic Dynamics" OR "Industrial and Corporate Change" OR "Research Policy" OR "Economics of Innovation and New Technology") AND TX ("Evolutionary Economics" OR "Neo-Schumpeterian")) OR SU ("Evolutionary Economics" OR "Neo-Schumpeterian")) **AND TX ("bounded* rational*")**	312	6,16	-
Basisalgorithmus 1 und Bezug zu Herbert Simon bzw. zur Carnegie-School	((SO ("Journal of Economic Issues" OR "Journal of Evolutionary Economics" OR "Journal of Institutional Economics" OR "Evolution-ary and Institutional Economics Review" OR "Journal of New Technology and Innovation" OR "Structural Change and Economic Dynamics" OR "Industrial and Corporate Change" OR "Research Policy" OR "Economics of Innovation and New Technology") AND TX ("Evolutionary Economics" OR "Neo-Schumpeterian")) OR SU ("Evolutionary Economics" OR "Neo-Schumpeterian")) **AND TX ("Herbert Simon" OR "Simon H.A." OR "Simon H." OR "Simon Herbert A." OR "Carnegie" OR "Carnegie-School" OR "Carnegie School")**	200	3,95	-
Basisalgorithmus 2	((SO ("Journal of Economic Issues" OR "Journal of Evolutionary Economics" OR "Journal of Institutional Economics" OR "Evolution-ary and Institutional Economics Review" OR "Journal of New Technology and Innovation" OR "Structural Change and Economic Dynamics" OR "Industrial and Corporate Change" OR "Research Policy" OR "Economics of Innovation and New Technology") AND TX ("Evolutionary Economics" OR "Neo-Schumpeterian")) OR SU ("Evolutionary Economics" OR "Neo-Schumpeterian")) **AND TX (innovat* OR "R&D" OR invent* OR imitat*)**			
Basisalgorithmus 2 und beschränkte Rationalität	((SO ("Journal of Economic Issues" OR "Journal of Evolutionary Economics" OR "Journal of Institutional Economics" OR "Evolution-ary and Institutional Economics Review" OR "Journal of New Technology and Innovation" OR "Structural Change and Economic Dynamics" OR "Industrial and Corporate Change" OR "Research Policy" OR "Economics of Innovation and New Technology") AND TX ("Evolutionary Economics" OR "Neo-Schumpeterian")) OR SU ("Evolutionary Economics" OR "Neo Schumpeterian")) AND TX (innovat* OR "R&D" OR invent* OR imitat*) **AND TX ("bounded* rational*")**	239	0,05	13,03
Basisalgorithmus 2 und Bezug zu Herbert Simon bzw. zur Carnegie-School	((SO ("Journal of Economic Issues" OR "Journal of Evolutionary Economics" OR "Journal of Institutional Economics" OR "Evolution-ary and Institutional Economics Review" OR "Journal of New Technology and Innovation" OR "Structural Change and Economic Dynamics" OR "Industrial and Corporate Change" OR "Research Policy" OR "Economics of Innovation and New Technology") AND TX ("Evolutionary Economics" OR "Neo-Schumpeterian")) OR SU ("Evolutionary Economics" OR "Neo-Schumpeterian")) AND TX (innovat* OR "R&D" OR invent* OR imitat*) **AND TX ("Herbert Simon" OR "Simon H.A." OR "Simon H." OR "Simon Herbert A." OR "Carnegie" OR "Carnegie-School" OR "Carnegie School")**	155	0,03	8,45

Basisalgorithmus 2, prozedurale Rationalität und Anspruchsniveau	((SO ("Journal of Economic Issues" OR "Journal of Evolutionary Economics" OR "Journal of Institutional Economics" OR "Evolutionary and Institutional Economics Review" OR "Journal of New Technology and Innovation" OR "Structural Change and Economic Dynamics" OR "Industrial and Corporate Change" OR "Research Policy" OR "Economics of Innovation and New Technology") AND TX ("Evolutionary Economics" OR "Neo-Schumpeterian")) OR SU ("Evolutionary Economics" OR "Neo-Schumpeterian")) AND TX (innovat* OR "R&D" OR invent* OR imitat*) **AND TX ("bounded* rational*" OR "procedural* rational*") AND TX ("aspiration level" OR satisfi*)**	85	0,02	4,63
Basisalgorithmus 2, prozedurale Rationalität, Anspruchsniveau und Problemlösen	((SO ("Journal of Economic Issues" OR "Journal of Evolutionary Economics" OR "Journal of Institutional Economics" OR "Evolutionary and Institutional Economics Review" OR "Journal of New Technology and Innovation" OR "Structural Change and Economic Dynamics" OR "Industrial and Corporate Change" OR "Research Policy" OR "Economics of Innovation and New Technology") AND TX ("Evolutionary Economics" OR "Neo-Schumpeterian")) OR SU ("Evolutionary Economics" OR "Neo-Schumpeterian")) AND TX (innovat* OR "R&D" OR invent* OR imitat*) **AND TX ("bounded* rational*" OR "procedural* rational*") AND TX ("aspiration level" OR satisfi*) AND TX ("problem solving" OR "problem-solving")**	21	0,00	1,15
Basisalgorithmus 2 und prozedurale Rationalität	((SO ("Journal of Economic Issues" OR "Journal of Evolutionary Economics" OR "Journal of Institutional Economics" OR "Evolutionary and Institutional Economics Review" OR "Journal of New Technology and Innovation" OR "Structural Change and Economic Dynamics" OR "Industrial and Corporate Change" OR "Research Policy" OR "Economics of Innovation and New Technology") AND TX ("Evolutionary Economics" OR "Neo-Schumpeterian")) OR SU ("Evolutionary Economics" OR "Neo-Schumpeterian")) AND TX (innovat* OR "R&D" OR invent* OR imitat*) **AND TX ("procedural* rational*) NOT TX ("bounded* rational*")**	10	0,00	0,55

7.2. Anhang zu Abschnitt 4.3

Appendix A. Supplement to the descriptive statistics[139]

The questionnaire contained over 100 items, of which approximately 30% were used in the present study. Apart from the questions about, for instance, turnover, employee numbers and R&D expenditure, the questions were scaled on a six-point scale (end-point scale).The missing values were analysed by means of the 'Missing Value Analysis' tool in SPSS; in this process, the variable 'R&D costs as proportion of turnover' was excluded from the analysis because of missing values of over 30%; the remaining missing values had a maximum value of 6.5% per item and case, and the median of the number of missing values was 0,2%; these missing values were estimated by means of an EM estimation in SPSS. The variables that cover the number of employees and the proportion of the staff involved in R&D were addressed by logarithm because of the high levels of skewness and kurtosis (Hair et al., (2012)). All respective latent variables proposed in the model are based on reflective multi-items scales.

Latent variables, their indicators and the corresponding questions in the questionnaire; mean values and standard deviations; percentage

Latent variables	Items	Questions	$\bar{x}$	sd
EcoInnoInt-Reg	EcoIntEx	To what extent will your company, in the next five years, take into account the aspects relating to article 4(1) ELVD in product development?	3.63	1.50
	EcoIntRs	To what extent will your company, in the next five years, expend resources for product development as stated in article 4(1) ELVD?	2.66	1.30
EcoGo-Ov (H1a/b)		Goal of product development in general:		
	EcGoRg	… compliance with environmental legislation	4.81	1.31
	EcGoEcBa	… improving ecological balance	3.62	1.32
	EcGoEcFe	… improving ecological features	3.95	1.35
	EcGoEcCo	… improving environmental compatibility	4.64	1.28
EcoGo-Reg (H1a/c)		Goal of product development related to article 4(1) ELVD especially:		
	EcGoRegRM	… use of recycled materials	3.33	1.64
	EcGoRegED	… ease of disassembly	3.25	1.48
	EcGoRegPR	… potential for reuse	2.99	1.59
	EcGoRegRy	… recycling	3.54	1.53
InnoAtt (H2a)	InAtSM	Without product development, our company cannot survive on the market.	5.16	1.26
	InAtCC	Product developments are an important component of our corporate culture.	5.14	1.05
	InAtRi_Re	Product developments are generally linked with excessively high risks. (recoded)	4.29	1.37
	InAtCG	Product developments are important for the attainment of our corporate goals.	5.48	0.83
	InAtRC	Product developments are important for the reputation of the company.	5.16	1.00

[139] Because of lack of space not all relevant tables and measures are presented in the Appendix but are available from the author upon request.

Latent variables	Items	Questions	$\bar{x}$	sd
EcoProac (H2b)	EcPrBv	Our company usually adapts to the requirements of environmental laws and regulations before they come into force.	4.25	1.48
	EcPrWh	We always implement the environmental laws and regulations affecting our company promptly when they come into force.	5.02	1.10
	EcPrNc_Re	We generally fulfil environmental laws and regulations only to the extent absolutely necessary. (recoded)	3.73	1.61
	EcPrId	Our company takes into account ecological aspects of product design and production independent of legislation.	4.33	1.29
InnoTrait (H3a)		Characteristic of the company:		
	ITWE	… willingness to experiment	4.45	1.16
	ITNO	… ability to seize new opportunities	4.74	1.01
	ITWR	… willingness to take risks	4.10	1.17
	ITCR	…creativity	4.31	1.13
	ITQI	We can quickly adopt and implement interesting ideas for product development	4.89	1.00
EcoInnoRess (H3b)	EcIRC	Excessively high costs make it difficult to take into account the aspects relating to article 4(1) ELVD in product development.	2.86	1.52
	EcIREK	A lack of expert knowledge makes it difficult to take into account the aspects relating to article 4(1) ELVD in product development.	2.46	1.40
	EcIIn	A lack of information about the topic makes it difficult to take into account the aspects relating to article 4(1) ELVD in product development.	3.04	1.58
DyEcoInno Past (H3c)	InnoPast	Dummy: has your company, in the last five years, taken into account the aspects relating to article 4(1) ELVD in product development?	yes: 38%; no: 62%	
InnoConstGo (H4)		Goal of product development:		
	CGR	…improving returns	5.06	1.09
	CGC	… lowering production costs	5.20	1.05
	CG	… raising unit cost return	5.10	1.01
EcProg (H5a)		Prognosis:		
	EcPT	… turnover in the next five years	3.96	0.95
	ECPP	… profit in the next five years	3.49	1.06
	ECPE	… number of employees in the next five years	3.30	0.89
EcoCrisReg (H5b)	ECR	In the context of the crisis in the automotive industry, our company will in future invest more in product improvement as stipulated in article 4(1) ELVD.	2.48	1.23
InnoInt	InnoIntEx	To what extent will your company, in the next five years, conduct product innovations to be used in passenger cars	5,51	940
	InnoIntRs	To what extent will your company, in the next five years, expand resources for product innovations to be used in passenger cars.	4,45	1,34
	R&D	Proportion of total number of employees working in R&D (log.)	20,2	56
	Dy1st tier	Dummy: suppliers on the first tier of the value chain	Yes: 34%; no: 66%	
	Size	Number of employees (log.)	1865	7000

In the questionnaire, the questions themselves did not mention article 4(1) of the ELVD but the identical German transposition in the 'Altfahrzeugverordnung', thereby explicitly referring to the single aspects.

Correlations among the indicators

	EcoIntEx	EcoIntRs	EcGoRg	EcGoEcBa	EcGoEcFe	EcGoEcCo	EcGoRegRM	EcGoRegED	EcGoRegPR	EcGoRegRy	InAtSM	InAtCC	InAtRi_Re	InAtCG	InAtRC	EcPrBv	EcPrWh	EcPrNc_	EcPrId	ITWE	ITNO	ITWR	ITCR	ITQI	EcIRC	EcIREK	EcIIn	CGR	CGC	CG	EcPT	ECPP	ECPE	ECR	InnoIntEx
EcoIntEx																																				
EcoIntRs	,750**																																			
EcGoRg	,142*	,250**																																		
EcGoEcBa	,209**	,337**	,397**																																	
EcGoEcFe	,234**	,335**	,411**	,573**																																
EcGoEcCo	,265**	,314**	,535**	,395**	,444**																															
EcGoRegRM	,413**	,455**	,285**	,335**	,283**	,438**																														
EcGoRegED	,467**	,478**	,296**	,344**	,270**	,406**	,478**																													
EcGoRegPR	,612**	,545**	,189**	,206**	,269**	,308**	,568**	,559**																												
EcGoRegRy	,470**	,425**	,253**	,208**	,259**	,482**	,521**	,515**	,667**																											
InAtSM	,024	,121*	,279**	,108	,119*	,149*	,066	,090	,027	-,001																										
InAtCC	,009	,142*	,253**	,089	,109	,159**	,028	,059	-,002	,005	,612**																									
InAtRi_Re	,151*	,130*	,066	,011	,010	,057	,053	,023	,141*	,082	,224**	,321**																								
InAtCG	,053	,120*	,236**	,057	,131*	,148*	,048	,037	-,006	-,047	,571**	,594**	,226**																							
InAtRC	,095	,167**	,296**	,153*	,155**	,144*	,060	,084	,001	-,030	,657**	,616**	,244**	,540**																						
EcPrBv	,067	,116	,372**	,246**	,231**	,325**	,107	,124*	,021	,136*	,323**	,286**	,117	,250**	,321**																					
EcPrWh	,057	,123*	,331**	,171**	,131*	,338**	,129*	,116	,066	,091	,351**	,277**	,153*	,274**	,279**	,603**																				
EcPrNc_Re	,161*	,194**	,150*	,172**	,123*	,093	,091	,009	,098	,092	,180**	,134*	,203**	,130*	,122*	,289**	,276**																			
EcPrId	,179**	,287**	,288**	,313**	,291**	,372**	,226**	,167**	,168**	,186**	,245**	,216**	,098	,183**	,232**	,453**	,419**	,285**																		
ITWE	,056	,110	,076	,183**	,185**	,106	,046	,185**	,094	,139*	,174**	,242**	,020	,227**	,184**	,166**	,145*	,020	,146*																	
ITNO	,110	,264**	,209**	,186**	,172**	,176**	,037	,219**	,141*	,093	,307**	,432**	,062	,332**	,299**	,304**	,323**	,122*	,240**	,498**																
ITWR	,104	,156**	,103	,195**	,083	,100	,011	,123*	,082	,115	,123*	,170**	-,029	,099	,047	,090	,163**	,029	,131*	,513**	,518**														
ITCR	,074	,186**	,199**	,256**	,251**	,267**	,116	,164**	,127*	,102	,279**	,388**	,018	,295**	,323**	,235**	,251**	,072	,267**	,543**	,642**	,498**													
ITQI	,109	,194**	,175**	,109	,147*	,123*	,129*	,096	,126*	,084	,297**	,437**	,072	,365**	,259**	,186**	,234**	,041	,176**	,336**	,450**	,341**	,402**												
EcIRC	,072	,023	-,050	,076	,056	-,045	,003	-,057	,044	,049	,024	,015	,077	,073	,089	,054	-,030	,205**	,034	-,057	-,080	-,040	-,078	,024											
EcIREK	,091	,104	,061	,032	-,011	,076	,033	-,002	,016	,040	,201**	,165**	,224**	,163**	,216**	,130*	,179**	,213**	,112	-,007	-,003	,060	,070	,036	,380**										
EcIIn	-,115	-,140*	,041	-,115	-,140*	,043	-,095	-,079	-,175**	-,074	,037	-,018	-,008	,115	,045	,133*	,110	-,042	-,023	-,106	-,006	-,021	-,046	-,015	,182**	,390**									
CGR	,124*	,144*	,250**	,086	,066	,232**	,262**	,136*	,146*	,181**	,194**	,159**	,115	,256**	,109	,102	,035	,048	,134*	-,050	,073	-,013	,033	,099	,054	,186**	,066								
CGC	,115	,123*	,182**	,158**	,058	,195**	,236**	,268**	,118*	,225**	,123*	,113	,028	,143*	,123*	,040	,003	-,052	,101	,069	,086	,064	,051	,052	,037	,136*	,037	,337**							
CG	,141*	,126*	,232**	,084	,019	,195**	,203**	,166**	,177**	,244**	,080	,075	,021	,170**	,104	,056	,056	-,044	,058	,009	,070	,019	,074	,080	,073	,143*	,065	,649**	,538**						
EcPT	,100	,123*	,115	-,018	-,010	,077	-,021	-,016	-,003	-,067	,301**	,268**	,259**	,250**	,135*	,104	,220**	,136*	,124*	,042	,117	,071	,026	,245**	,051	,178**	-,061	,196**	,044	,097					
ECPP	,061	,109	,086	-,020	-,069	,031	,012	,015	-,030	-,079	,300**	,208**	,166**	,210**	,181**	,104	,209**	,097	,074	,044	,192**	,020	,073	,234**	,077	,164**	,046	,226**	,062	,163**	,644**				
ECPE	,035	,032	,097	,023	-,004	,016	,022	,020	,037	-,083	,174**	,183**	,152*	,124*	,077	,017	,085	,018	-,033	,165**	,135*	,089	,134*	,275**	-,012	,008	-,025	,074	-,025	-,036	,539**	,490**			
ECR	,493**	,570**	,174**	,290**	,240**	,255**	,410**	,421**	,483**	,365**	,008	,094	,092	,036	-,046	,052	,144*	,075	,215**	,122*	,187**	,148*	,174**	,132*	-,098	-,056	-,162**	,134*	,131*	,064	,102	,023	,092		
InnoIntEx	,015	,025	,065	-,049	,027	,017	,051	,021	,024	-,021	,407**	,323**	,206**	,363**	,296**	,194**	,222**	,082	,064	,003	,062	-,061	,047	,205**	,115	,165**	,120*	,181**	,129*	,103	,259**	,242**	,161**	-,019	
InnoIntRs	,089	,188**	,199**	,116	,170**	,098	,128*	,071	,039	,009	,388**	,377**	,138*	,337**	,316**	,210**	,168**	,087	,062	,025	,137*	,039	,149*	,278**	,162**	,195**	,105	,200**	,188**	,121*	,211**	,149*	,170**	,069	,609**

Appendix B. CEIS-Model

Appendix B1. Outer model indices

Latent variable coefficients

Endogenous variable / Coefficients	EcoGo-Ov	EcoGo-Reg	EcoInnoInt-Reg	EcoProac	InnoTrait	InnoConstGo	InnoAtt	EcProg	EcoInnoRess
Composite reliability	0,854	0,888	0,933	0,826	0,874	0,861	0,874	0,878	0,783
Cronbach's alpha	0,773	0,831	0,857	0,717	0,818	0,756	0,816	0,791	0,582
Averange variance extracted	0,595	0,665	0,875	0,547	0,583	0,675	0,591	0,706	0,548

Correlations among the latent variables and Fornell-Larcker criterium (in the diagonal)

Endogenous variable / Exogenous variable	EcoGo-Ov	EcoGo-Reg	EcoInnoInt-Reg	EcoProac	InnoTrait	InnoConstGo	InnoAtt	EcoCrisReg	EcProg	EcoInnoRess
EcoGo-Ov	0,771									
EcoGo-Reg	0,477***	0,815								
EcoInnoInt-Reg	0,362***	0,635***	0,936							
EcoProac	0,441***	0,188**	0,204***	0,740						
InnoTrait	0,284***	0,179**	0,190**	0,310***	0,764					
InnoConstGo	0,228***	0,291***	0,168**	0,078	0,074	0,822				
InnoAtt	0,238***	0,049	0,134*	0,397***	0,388***	0,200***	0,769			
EcoCrisReg	0,311***	0,516***	0,568***	0,164**	0,201***	0,130*	0,037	-		
EcProg	0,041	-0,025	0,099	0,160**	0,184**	0,133**	0,301***	0,086	0,840	
EcoInRess	-0,006	0,036	-0,016	-0,165	0,029	-0,153	-0,172	0,138	-0,085	0,740

*Significant at <0,05 level (2-tailed); significant at <0,01 level (2-tailed); significant at <0,001 level (2-tailed)

Appendix B2. Inner model indices

Coefficients of determinations R^2 with and without exogenous variable; R^2 adjusted (Lord 1); path coefficients β (direct and total); effect size f^2 of β (direct and total); predictive relevance Q^2

Endogenous variables	Coefficients / Exogenous variables	$R^2_{adj.}$	R^2	R^2 without exogenous variable	β direct	β total	f^2 direct β	f^2 total β	Q^2
EcoGoOv	EcoProac	0,25	0,28	0,16	0,393***	0,393***	0,173	0,173	0,29
	DyEcoInnoPast			0,27	0,124**	0,124**	0,022	0,022	
	EcoInnoRess			-	0,075	0,075	0	0	
	InnoAtt			-	0,013	0,013	0,003	0,003	
	InnoTrait			0,26	0,146*	0,146*	0,041	0,041	
	InnoConstGo			0,25	0,191***	0,191***	0,043	0,043	
	EcProg			-	-0,073	-0,073	0,003	0,003	
EcoGo-Reg	EcoGo-Ov	0,42	0,45	0,36	0,354***	0,354***	0,169	0,169	0,45
	EcoProac			-	0,034	0,173***	0,006	0,033	
	DyEcoInnoPast			0,28	0,414***	0,457***	0,205	0,227	
	EcoInnoRess			-	0,031	0,058	0,001	0,002	
	InnoAtt			0,44	- 0,135**	-0,13**	0,007	0,006	
	InnoTrait			0,44	0,087*	0,139**	0,016	0,025	
	InnoConstGo			0,42	0,193***	0,26***	0,056	0,076	
	EcProg			-	-0,047	-0,073	0,001	0,002	
EcoInnotIn-Reg	EcoGo-Ov	0,58	0,60	-	0,055	0,164***	0,02	0,059	0,6
	EcoGo-Reg			0,55	0,308***	0,308***	0,196	0,196	
	EcoProac			-	0,029	0,104**	0,006	0,021	-
	DyEcoInnoPast			0,50	0,364***	0,512***	0,228	0,32	
	EcoInnoRess			-	-0,063	-0,041	0,001	0,001	-
	EcoCrisReg			0,56	0,239***	0,239***	0,136	0,136	
	InnoAtt			-	0,024	-0,015	0,003	0,002	-
	InnoTrait			-	0,023	0,074*	0,004	0,014	-
	InnoConstGo			-	-0,033	0,058	0,006	0,01	-
	EcProg			0,59	0,064*	0,037	0,006	0,004	

*Significant at <0,05 level (2-tailed); significant at <0,01 level (2-tailed); significant at <0,001 level (2-tailed)

Appendix B3. Control Variables

Coefficients of determinations R^2 (for R^2 without exogenous variable see Appendix A2; R^2 adjusted (Lord 1); path coefficients β (direct and total); effect size f^2 of β (direct and total); predictive relevance Q^2

Coefficients	R^2_{adj}			β direct			β total			f^2 direct β			Q^2		
Endogenous variables / Exogenous variables	EcoGo-Ov	EcoGo-Reg	InnoInt-Reg	EcoGo-Ov	EcoGo-Reg	InnoInt-Reg	EcoGo-Ov	EcoGo-Reg	InnoInt-Reg	EcoGo-Ov	EcoGo-Reg	InnoInt-Reg	EcoGo-Ov	EcoGo-Reg	InnoInt-Reg
LNSize	0,24	0,42	0,57	-0,017	-0,001	0,006	0,002	0,001	0,000	0,002	0	0,001	0,29	0,45	0,60
LNR&D	0,25	0,44	0,58	0,073	-	-0,012	0,011	0,015	0,001	0,011	0,018	0	0,29	0,47	0,60
1st tier	0,25	0,42	0,58	0,081	-0,003	0,028	0,011	0,003	0,005	0,011	0	0,004	0,292	0,45	0,60

*Significant at <0,05 level (2-tailed); significant at <0,01 level (2-tailed); significant at <0,001 level (2-tailed)

Appendix C. Model with the endogenous Variable InnoInt

Latent variable coefficients for the model with InnoInt

Exogenous variable / Coefficients	InnoInt	InnoAtt	InnoTrait	InnoConstGo	EcProg
Composite reliability	0,892	0,874	0,874	0,861	0,878
Cronbach's alpha	0,757	0,816	0,818	0,756	0,791
Averange variance extracted	0,805	0,591	0,583	0,675	0,706

Coefficients of R^2 adjusted (Lord 1); path coefficients β (direct and total); effect size f^2 of β (direct and total); predictive relevance Q^2

Coefficients / Endogenous variables / Exogenous variables	R^2_{adj}	β direct				β total				f^2 direct β				Q^2
		InnoAtt	InnoTrait	InnoConstGo	EcProg	InnoAtt	InnoTrait	InnoConstGo	EcProg	InnoAtt	InnoTrait	InnoConstGo	EcProg	InnoAtt
InnoInt	0,23	0,500***	-0,72	0,106*	0,132**	0,443***	0,090	0,106*	0,132**	0,209	0,010	0,022	0,035	0,26
InnoAtt	0,14		0,388***				0,388***				0,151			0,15

*Significant at <0,05 level (2-tailed); significant at <0,01 level (2-tailed); significant at <0,001 level (2-tailed)

7.3. Anhang zu Abschnitt 4.4

Free fields indicate the failure of the cooperation, the values of KD and TrD are given independently of the success

variations of π_i*

	agent type	n	π_i	t (inno)	KD	KDT	TrD	TrDT	OI
default	STANDARD	1	0.015	66	11.5	0.2	30.9	0.5	5.4
	OPPORTUNIST	1			11.5	0.2	30.9	0.5	5.4
	TRUST	1			11.5	0.2	30.9	0.5	5.4
	STANDARD	1	0.05		-0.9		8.9		
	OPPORTUNIST	1			-0.9		8.9		
	TRUST	1			-0.9		8.9		
setting 1.1	STANDARD	1	0.015	67	8.6	0.1	7.6	0.1	1.0
	OPPORTUNIST	1			10.4	0.2	6.8	0.1	1.1
	TRUST	1			7.9	0.1	6.6	0.1	0.8
	STANDARD	1	1.5	67	7.8	0.1	-0.3	0.0	0.0
	OPPORTUNIST	1			9.7	0.1	-0.2	0.0	0.0
	TRUST	1			7.2	0.1	-0.8	0.0	-0.1
setting 2.3	STANDARD	1	0.015	72	5.5	0.1	26.0	0.4	2.0
	OPPORTUNIST	1			3.7	0.1	18.2	0.3	0.9
	TRUST	1			9.4	0.1	11.9	0.2	1.6
	STANDARD	1	2		-2.4		20.6		
	OPPORTUNIST	1			-1.1		19.3		
	TRUST	1			3.6		-3.4		

variations of δ_i *

	agent type	n	δ_i	t (inno)	KD	KDT	TrD	TrDT	OI
default	STANDARD	1	0.003	66	11.6	0.2	31.6	0.5	5.5
	OPPORTUNIST	1			11.6	0.2	31.6	0.5	5.5
	TRUST	1			11.6	0.2	31.6	0.5	5.5
setting 1.1	STANDARD	1	0.003	67	11.4	0.2	31.7	0.5	5.4
	OPPORTUNIST	1			12.2	0.2	31.6	0.5	5.8
	TRUST	1			10.7	0.2	30.9	0.5	4.9
setting 2.3	STANDARD	1	0.003	71	5.5	0.1	26.0	0.4	2.0
	OPPORTUNIST	1			3.7	0.1	18.1	0.3	0.9
	TRUST	1			9.3	0.1	12.2	0.2	1.6
	STANDARD	1	0.007		3.9		34.8		
	OPPORTUNIST	1			2.2		19.8		
	TRUST	1			6.2		16.2		

*Free fields indicate the failure of the cooperation, the values of KD and TrD are given independendly of the success

7.4. Anhang zu Abschnitt 4.5

Core of the simulation model (Pseudo-code)

```
Determine component forces {
        Determine component force for slack-based search (cf. eq. 5)
        Determine component force for profit aspiration (cf. eq. 1)
        Determine component force for market share aspiration (cf. eq. 2)
}
Determine aggregate forces {
        Determine innovation force (cf. eq. 6)
        Determine imitation force (cf. eq. 4)
        Determine routine force (cf. eq. 7)
}
IF ((innovation force OR imitation force)>routine force){
        action mode := innovation mode
}ELSE{
        action mode := routine mode
}
IF (action mode=innovation mode){
        Shall perform knowledge acquisition := FALSE;
        IF (is agent currently involved in individual innovation project = TRUE OR
            is agent currently involved  in cooperative project = TRUE){
                Shall perform knowledge acquisition := TRUE;
        }ELSE{
                IF (willingness to cooperate < threshold value for cooperation (cf. eq. 9 and 10)){
                        Start new individual innovation project
                        Shall perform knowledge acquisition  := TRUE;
                        Type of knowledge acquisition := individual knowledge acquisition
                }ELSE IF (willingness to cooperate >= threshold value for cooperation (cf. eq. 9 and 10)){
                        Identifiy potential cooperation partners
                        IF (agent has potential cooperation partners  = TRUE){
                                Select cooperation partner
                                shall perform knowledge acquisition := TRUE;
                                type of knowledge acquisition := cooperative knowledge acquisition
                        }ELSE{
                                shall perform knowledge acquisition := FALSE;
                                type of knowledge acquisition := individual knowledge acquisition
                        }
                }
        }
}
IF (shall perform knowledge acquisition = TRUE){
        IF (type of knowledge acquisition = individual  knowledge acquisition){
        Try to acquire new knowledge individually
        }ELSE IF (type of knowledge acquisition = cooperative knowledge acquisition){{
                Try to acquire new knowledge from cooperation partner
        }
        IF(current time step = predefined end of innovation project){
                IF(is end of project reached = TRUE){
                        Terminate innovation project successfully
         }
                ELSE{
                Continue project next round
        }
        ELSE{
                Terminate innovation project unsuccessfully
        }
}
Determine turnover and profits
Update aspiration level (cf. eq. 3a/b)
Terminate unprofitable projects
```