HETEROGENEOUS RESEARCH NETWORKS AS INTERFACES: COMMIT AND SURVIVAL OF ORGANISATIONS AROUND UNIVERSITY RESEARCH. THE CASE OF BIOTECHNOLOGY IN THE NETHERLANDS

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Abstract

In this paper social network terms are applied to conceptualize the intermediary sector of heterogeneous research networks between the institutional contexts of university research and industrial research. White's notion of 'commit interface', and Burt's elaboration of this notion to account for change in social networks, are used to explain changes in research networks comprising research institutes, agencies and industrial firms. The theory is tested for the case of a subsystem of the Dutch innovation system: university research in biotechnology with applications in the sectors of environmental research, agriculture and health. The analysis reveals that structural autonomous organizational actors in such networks show different types of behavior than predicted in the hypotheses of Burt: some show less role conforming behavior, others however show role conforming behavior, but both tend to have higher survival rates. Moreover, processes of change in the network also result in the occurrence of structural autonomous actors in later stages of the development of the network. White's notions of differentiation and dependence are used to account for the differences between the attributes of the network studied and the networks initially analyzed by Burt, i.e. economic markets.

Key words: research networks, university research, industrial research, biotechnology

1. Introduction

Traditionally, scientific research was performed in relatively closed institutional contexts: fundamental scientific research was predominantly performed in the context of universities and peripheral research institutes, while applied and application oriented scientific research was predominantly performed in the context of industrial and governmental research institutes and laboratories.

Various tendencies have resulted in an increased blurring of the boundaries

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between these contexts. Universities increasingly perform application-oriented research to supplement their funds. Industrial research laboratories, especially in the new technology fields that strongly depend on scientific insights, focus more and more on strategic fundamental scientific fields (where they co-operate with academic research institutes).

In line with these developments, co-operation between research institutes that belong to different institutional contexts has increased.

As a result a new intermediary context of heterogeneous research networks has emerged. These networks are heterogeneous because they comprise different types of organisational actors (academic research groups, industrial research laboratories, other research institutes and governmental agencies). Research being performed in this context conveys the intermediary nature of the context: it is called ‘pre-competitive’ to distinguish it from competitive, close to the market research and development; or ‘strategic fundamental’, to distinguish it from fundamental scientific research, or ‘application-oriented’ rather than applied scientific research.

The development of this intermediary context is an indication of a process of change in which research systems have come to be considered as part of so called innovation systems. The latter systems encompass all organisations and agencies dedicated to the research and development activities geared to the development of new products and processes. It is called an innovation system, because it is presupposed that the attuning of the various organisations and agencies involved in the development of new products and processes results in a systematic relationship between the institutional contexts of the system of science on the one hand, and the economy on the other.

However, in reality innovation systems differ in the extent to which relationships are activated and the extent to which such relationships, considered over a longer period of time, have a stable or fluid character. In other words, actual innovation systems differ in terms of the attributes of the heterogeneous networks comprising the innovation system.

Is the intermediary sector a constantly changing interface of interactions between actors from different institutional backgrounds, or is the sector characterised by the development of relatively stable configurations of actors from these different backgrounds? If the first observation is correct, the interface will not substantially change the institutional distribution of labour between the system of science and the economy; if the latter is the case, the emerging configurations can be the onset of new institutional developments.

In earlier discussions on change in research systems, two different positions can be distinguished. On the one hand empirical (quite often comparative) studies on the attributes of innovation systems presuppose that the innovation systems have replaced the earlier separated types of research systems (e.g. the clearly separated different systems of academic and industrial science).

On the other hand, one can distinguish the position that innovation systems exemplify research systems in transition. For example, the presumed change in the production of scientific knowledge, as formulated by Gibbons et.al. (1994) from
Mode 1 (based on science-internal objectives and criteria) to Mode 2 (science production related to science-external objectives) is according to the authors, related to the structural change of the system of science. To what extent the current state of affairs - indicated by the term innovation system – is a attribute of a system in transition, or exemplifies a new type of system is a question, that has not, until now, been addressed.

The objective of this paper is first, to conceptualise the social structure of an innovation system in terms of the heterogeneous research networks comprising it, as well as, second, to indicate the determinants of the process of change of the context.

The argument starts with the conceptualisation of the intermediary context as a commit interface (White, 1992) between the university and industrial contexts dedicated to the production of a particular type of research. National innovation systems differ as to the nature of this interface; the interface is differentially embedded in the surrounding institutional contexts. For example, in Europe national and international research programs emphasise co-operation between organisational actors from the different contexts. The subsequent EU Framework programs are good examples of this tendency. It is to be expected that the development of this intermediary context will be different in an innovation system where the co-operation between institutional contexts is determined by market forces. The differences in the nature of the innovation systems in Europe and the US are related to such differential effects.

The social structure of the intermediary context can be accounted for by assessing the nature of the structure of the networks resulting from the relationships between the various organisational actors. In an interesting combination of White’s notion of a commit interface and his own notion of structural holes, Burt formulates two hypotheses regarding the processes of change in commit interfaces. At the level of the participating actors, the commit hypothesis predicts a relationship between the structural position of actors and their behaviour and survival. At the collective level, the related survival hypothesis predicts the nature of change of the social structure as a result of the individual actions of the participants.

Applying these hypotheses to the intermediary context provides a theory concerning the process of change of the intermediary context.

The theory will be applied to account for the social structure of, and the process of change in, the heterogeneous research networks around university research in the field of biotechnology in The Netherlands. In a recent report for the Dutch Ministry of Economic Affairs (Van Rossum, 1999), the present author has described the (development of) heterogeneous research network structures in the Dutch innovation system at large. The present analysis is based on information from the participation of Dutch firms, research institutes and academic research groups in the research program of the national research council (i.e. of the research council for technical sciences, STW).

In order to exclude the effects that the nature of the heterogeneous networks will be different in various fields of science, the present analysis is confined to only one research field, i.e. biotechnology. This field was chosen because in The Netherlands
strong relationships exist between this field and its applications within especially the industrial sectors of environmental technology; health and agriculture.1

In the next paragraph the theory and the hypotheses are outlined. Thereafter, I will indicate the nature of the data and the methods used. In the fourth paragraph the hypotheses are tested. Finally, the results of the analysis are discussed, and consequences for further research along these lines are indicated.

2. Theoretical considerations

In order to conceptualise the intermediary context let me conceive of the utilisation of academic research as a form of production. Universities are then producers of academic research; specialised research institutes and industrial firms can then be considered as the (potential) consumers of this research. The production occurs in ‘commit interfaces’ (White, 1992) in which the three different types of organisational actors participate.

The realisation of these interfaces can take three different forms:

(1) A particular type of ‘research firm’ can be established in order to transform university research into a product. The prime example of this form is the spin-off firm from university research, such as in biotechnology the so called Dedicated Biotechnology Firms (DBF’s)

(2) University research groups, specialised research institutes and industrial firms can co-operate in joint research projects to actually develop the research products. The cooperative research projects in programs such as the EU Framework Programs and EUREKA are examples of this form of interface.

(3) University research can be considered by specialised research institutes and industrial firms as a resource that is of interest for them. In this case the latter organisational actors act as actual consumers of the university research. The research projects that will be the subject of the next paragraphs are examples of this form of commit interface: specialised research institutes and industrial firms act as potential consumers of particular research projects.

National innovation systems are characterized by a differential attention to these forms of interfaces: in some the development of research firms will be emphasized; in others the joint research projects or research commission relationships.

The degree of control in such interfaces has specific attributes. The interest of the participating organisational actors in the interface is only partly related to their main organisational objectives: the main (research) objective of universities is the furtherance of knowledge; the objective of firms is the production of particular goods or services. Hence their interest in the interface is only secondary. Only in the

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1 This is a work in progress; in the near future, analyses of various disciplines, will be combined in a multilevel analysis of the social structure of the total Dutch innovation system.
case of specialised research institutes the main objective – developing particular types of research – is closely related to the objective of the interface.

As a result, the extent to which activity within the interface is controlled from the different institutional contexts is a variable, and depends on the nature of the social structure of the intermediary context.

Consequently, one may find variations in the nature of two of the dimensions distinguished in commit interfaces by White, i.e. in the ‘dependence’ and ‘differentiation’ of the interfaces, comparing either scientific fields or innovation systems. The third dimension, involuteness or specialisation of the interface, is in this case a constant: involuteness of this intermediary context is infinite.²

White defines the dimension of ‘differentiation’ as: “… the extent to which the ordering of entities by valuation inside the discipline correlates in its reception outside”. (Ibid. p. 35) Differentiation then refers to the cognitive aspects of the interface. Considering the fact that the interface studied here is located in between institutional contexts, the degree of differentiation is relatively low (I did already indicate the various terms by which the production within the interface is circumscribed). From the point of view of the scientific system, the type of research being performed within this interface will be defined as ‘multidisciplinary’; from the point of view of the economic system research in this interface will be defined as ‘pre-competitive’. Both accounts exemplify the low level of differentiation of this particular interface.

White defines dependence as: “… how the upstream valuation of each action or flow unit, in social and/or physical production, from a discipline correlates with its valuation downstream.” (White, op.cit., p.35).

Given the different institutional backgrounds of the participants in the interface, upstream and downstream valuations do not necessarily overlap. Moreover, the extent of correlation between up- and downstream valuation will differ among the various forms of interfaces. One may, for example, expect that, in the case of the first form of interface, i.e. the use of research firms, the correlation of up- and downstream valuation is especially high: research firms particularly develop research that is, in their view, directly useful for other firms. In the other forms, the degree of correlation between up – and downstream correlation will vary according to the nature of the social structure of the commit interfaces. When, for example, firms have a more structural autonomous position in the network structure of the

² White defines involuteness or specialisation as: “ … the extent to which the given valuation ordering refers to and presupposes other orderings outside the given discipline” (White, op.cit., p.35). The relationship between the commit interface studied here with the surrounding economic and scientific systems, makes this interface in terms of involuteness infinite: the sector is simultaneously characterized by two valuations, one from the scientific and another from the economic system. For this reason the assessment of project proposals under the aegis of the research council for the technical sciences always entails two subsequent refereeing rounds: a first in which the scientific quality of the proposal is assessed and a second in which the economic usefulness of the proposed products of the project is judged.
interface, the degree of dependence on the surrounding institutional context of the
economic system will be greater than when they do not occupy such positions.
Conversely, a more structural autonomous position of the universities or research
institutes will make the interface more dependent on the research system.

How then can we conceptualise the social structure of the interface?
The starting point is the fact that the interface is characterized by relationships
between the various organisational actors. The relationships are of various kinds:
e.g. the agreements of research firms with universities and industrial firms; the joint
involvement of universities, research institutes and industrial firms in research
projects; and the involvement of research institutes and industrial firms with
university research as (potential) consumers.

Interfaces thus result at the collective level of, for example, scientific fields, in
network structures in which the actors occupy different positions.3

The analysis of the degree of dependence within the interface can then be
restated as the extent to which the actual social structure of the intermediary sector is
linked to the surrounding institutional contexts.

According to Burt (1992), positions in networks differ regarding to the number
and type of contacts the actor who occupies the position can have. Burt emphasizes
that actors can use their contacts strategically. The degree to which this is possible is
related to the number of non-redundant contacts. ‘Structural holes’ are non-
redundant contacts (in a similar argument, Granovetter defines these non-redundant
contacts as ‘weak ties’). An actor is structural autonomous when he has a network
that is “ … free of structural holes at [his] own end and rich in structural holes at the
other end.” (Burt, 1992: p.45). In other words, while in general a network structure
determines the action of participants in the network; some actors can ‘avoid’ the
structural influence of the network by strategically use the (non-redundant) contacts
they have. The opposite reasoning of course is that actors that occupy structurally
equivalent positions (and lack non-redundant contacts) will have to conform to the
norms of the network.

Burt further elaborates his argument to account for processes of change in the
network resulting from the commit interfaces. (Burt, op.cit.: p. 197)

Actors lacking structural autonomy have to conform more closely to the behavior
characteristic for their position in the social structure. Consequently, if they do not
perform their role in an adequate way they will be in their role for a shorter period of
time. Thus, if we compare the network in different periods of time, less structural
autonomous actors should conform more closely to their role, but also stay for
shorter periods of time in the network.

3 The initial motivation of this study was a project started under the aegis of the OECD to
map the national innovation systems of the member countries by means of the networks of
relationships between different types of organisational actors. The indication of networks
at the national level, however, ignores the large differences in this respect between
scientific fields. It is therefore our intention to approach the problem of the mapping of
innovation systems via a multi-level approach. The present paper is a first attempt to
make a mapping at the lowest level, i.e. the intermediary sector of one scientific field.
Similarly, organisational actors with a high degree of structural autonomy should show more varied behavior and stay longer in the network. Hence we can state the following hypotheses:

Hypothesis 1: Structural autonomous actors show more varied behavior.

Hypothesis 2: Structural autonomy and length of stay in the network are positively related.

Burt presupposes in this argument that the ordering within the commit interface is clear, both for the actors involved and for the surrounding actors (e.g. in the case of economic markets as a result of the consensus about a market schedule). The commit interface can then be considered as a clearly separated arena (e.g. economic markets). In such interfaces the differentiation is maximal and dependence minimal. Consequently, change in the interface is only related to the differences in structural positions of the actors in the networks.

However, in the case of the intermediary research sector that is the focus of this paper, the ordering within the sector is not clearly separated from the institutional contexts, hence the possibility that other (social) factors influence the ordering and, consequently, the process of change in the sector.

White’s notions of differentiation and dependence can then be used to formulate the nature of the ‘embeddedness’ of the intermediary sector in the two major surrounding sectors, i.e. the scientific and the economic sector. More in particular, White presupposes that an ordering in a social context is sustained by a specific combination of two of the embedding ratio’s (considering that one of the ratio’s – in our case involuteness is a constant (White, 1992: 36)). In our case, one may thus presuppose that the sustainability of the intermediary context as a separate social structure is a result of the effects of embeddedness as a result of, respectively, the levels of differentiation and dependence. Consequently, the initial hypotheses derived from Burt’s theory of change in commit interfaces have to be modified, considering the effects of differentiation and dependence.

The level of differentiation can be measured by analyzing the extent to which the actors belong to separate categories within the two institutional contexts. For example, when all actors have relationships within one scientific field, e.g. biology, the intermediary sector could be described as a special subfield of this discipline. Similarly, when all participating firms are part of the same industry, the intermediary sector would be a subsector of this industry. Valuation within the intermediary sector would, in the first instance use criteria derived from the discipline of biology; in the second instance from the industry at hand.

In fact, the networks comprise universities, research institutes and firms from a multitude of scientific disciplines and industries. Instead of attempting to formulate the exact nature of the combination of embedding ratio’s for dependence and differentiation that facilitates sustainability of the intermediary context, one can also
conceive of the two embedding ratio’s as social factors influencing the nature of the social structure. Differentiation then measures the extent to which the valuation ordering of the two institutional contexts are represented in the intermediary context; dependence measures the extent to which differences in terms of structural autonomy within the intermediary sector overlaps with differences in either of the institutional contexts.4

Consequently, Burt’s hypothesis on the effects of structural autonomy can be modified:

Hypothesis 3: If structural autonomous organisations are especially related to a particular scientific field or are part of industry-specific network configurations, the interface will tend to develop as, respectively a subfield of the scientific field or a subsector of an industry.

If the structural autonomous actors are especially organisations from the university context, one may expect change as determined by attributes of the latter institutional context. If, on the other hand, the structural autonomous organisations are especially firms, change in the intermediary sector will be in the direction of the economic context.

More in particular, dependency on the university institutional context would reveal networks characterised by boundaries between disciplinary fields; dependency on the economic context would show networks characterised by boundaries between industries.

Our hypothesis 2 however predicts that structural autonomous organisations will reveal more varied behaviour that organisations that are not structural autonomous. Combining this prediction with hypothesis 3 results in a fourth hypothesis, namely that when organisations are more dependent on either the scientific or economic institutional context (as indicated in hypothesis 3); they will then especially show variation in the other context:

Hypothesis 4: If structural autonomous organisations are especially related to either a scientific field, or to networks that are industry specific, they will show variation in the other context.

These hypotheses will be tested in the case of the relationships around the field of biotechnology in the Dutch research system.

4 White conceives of differentiation and dependence as independent variables. This is in my view incorrect: less differentiation implies higher chances of dependence.
3. The empirical case: the network of organisational actors around one field of academic technical scientific research in The Netherlands, i.e. biotechnology

Biotechnology is considered one of the main fields in which new products and processes are directly related to the outcomes of fundamental scientific research. Consequently, one may expect, especially in this field, the emergence of an intermediary context of heterogeneous networks comprising organisations from different institutional contexts. While such heterogeneous networks are also explicitly created in (national and international) research programs in order to stimulate development of biotechnological research; also academic research in related academic fields, such as biology, chemistry, medical science and pharmacology is partly focused on biotechnological objectives. In this analysis, to avoid the effects of explicit policy decisions, we will focus on the latter type of scientific research. In particular, we use information on the projects financed by the Dutch research council for the technical sciences (STW) that are related to biotechnological topics.

STW’s main objective in funding academic scientific research in the technical sciences is that research projects in the technical sciences should not only have scientific but also economic merit. This policy is executed in two ways: (1) research proposals have to be judged not only on the potential scientific but also on the practical merit of the results and (2) each submission of a project proposal has to be accompanied by the names of other organisations (agencies; research institutes and/or industrial firms) that are potentially interested in the results of the study.

STW collects the information on projects, research groups and potential users in a database accessible via the internet (www.stw.nl). The projects are categorized according to the university affiliation, the field of technical science and the moment in which they were submitted.

Accordingly, this database can be used to analyze the relationships around university research in the various technical sciences for different periods of time. As will be indicated in the next paragraph projects will be analyzed for three subsequent periods of time.

While the database covers all technical scientific fields; in this paper I will confine the analysis to those projects related to the field of biotechnology.

4. Data and method

A relationship is defined as the involvement of two organisational actors (respectively an industrial firm, a research institute or another agency) with a research project executed by a university group. All research projects financed by the research council STW in the recent 10 - 15 years are coded according to respectively, the university in which the project is executed; the scientific field and a number. These numbers can be used to chronologically order the projects: for this analysis I have divided all projects in three consecutive time periods in order to
study the changes in the networks. The time periods are approximately evenly divided over the decade (though in the last years relatively more projects are financed).

At the moment of finishing the analysis (1999), the database comprises 1026 (current and finished) projects. These projects are executed at various Dutch universities and some research institutes, with special emphasis on the technical universities. The number of organisations and firms related to these projects (as indicated by the database) is 1617. Using the search term ‘biotechnology’ results in a subset of 81 projects dedicated to topics in the field of biotechnology. From these 81 biotechnology projects, 37 do not have information on the organisations involved with the project, and, in 5 cases, the project involves only one organisation. These 42 projects were omitted from the analysis.5

Accordingly the subsequent analysis is done with 39 projects involving 77 organisations (49 in the first, 23 in the second and 30 in the last subset – some organisations are involved in more than one subset).

The analysis of the networks has been done with Burt’s network analysis program STRUCTURE. This program also generated the network statistics variables for the analysis that will be used to elaborate the measuring of structural autonomy: power [the eigenvector in which the most powerful actor has the value 1] and percentage power reflected (percentage of interaction out that comes back)]. Structural autonomy itself has been operationalised in the following way. As relationships are defined as co-involvement in a research project as a potential user, structural autonomous actors are those actors that are involved in at least two projects in the same time period. Power and percentage power reflected are then used to indicate the differences between structural autonomous actors. Variation of behaviour is operationalised by measuring the number of different scientific fields with which the organisations are in general involved with in the case of STW projects.

Survival is measured by establishing the extent to which actors re-appear in the subsequent networks.

Differentiation is operationalised in two different ways. First, the differentiation from the scientific institutional context is measured by establishing the extent to which the relationships of the organisations are within the confines of one particular scientific field, or spread out over various scientific fields. The differentiation from the economic institutional context is operationalised by indicating the extent to which the respective networks are characterised by actors from particular industries.

Finally, dependence is operationalised by combining the information on the structural autonomy of organisations and their differentiation scores. Or, in other words, differentiation indicates the extent to which cognitive patterns can be discerned in the network, related to the respective institutional contexts; dependence measures the social aspects thereof.

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5 There is an overrepresentation of the earlier projects in the list of projects excluded from the analysis. Hence the actual analysis misses the characteristics of the early period of the development of biotechnology in The Netherlands.
5. Analysis

The field of biotechnology is in general characterised by co-operative links between firms, research institutes and other agencies (Arora and Gambardella, 1990). The network structures of the three subsets as shown in Figures 1 – 3 exemplify these collaborations. The tree diagrams in Figures 1 – 3 are based on the structural equivalence analysis of the relationships between the actors involved. Actors are close together if they occupy structural equivalent positions in the respective networks (structural equivalent equivalent actors have the same relationships with other actors). As indicated earlier, the universities are excluded from these networks. The links of the other actors are operationalised as their involvement within STW research projects executed in the various universities. As can be expected, the clusters in the networks show the various application areas of biotechnology (especially in the agribusiness (seeds), health and environmental applications).

The characteristics of the subsequent networks are indicated in Table 1. All three networks are characterised by a large variation of types of organisations. However, comparing the three subsequent networks, it is clear that the dominance of firms in the networks increases over the time period studied, while the relative position of research organisations decreases. Moreover, in all three networks a smaller set of very large firms (e.g. AKZO Nobel; DSM; Unilever) appears to play a significant part in the intermediary biotechnology research sector. The size of the companies is measured by establishing the number of STW projects firms are involved in. While in most cases firms are involved with 2 – 5 STW projects, some larger multinationals are involved with 70 – 100 STW projects. This reveals the significance of a small set of large Dutch multinationals for the Dutch research system. In the case of the biotechnology field, especially some chemical firms and food companies play such a significant role.

However, a specific attribute of the Dutch biotechnology sector is the predominant position of firms that are interested in the application of biotechnology in the production of seeds. The distribution of the industries over the three networks exemplifies this predominance. Especially in the first and the last networks seeds companies form a major part of the firms interested in biotechnology research. If we include in the analysis the number of research organisations in the same sector (in the table shown in the category ‘other’) the emphasis on this field of applications becomes even more strikingly visible.

In line with the emphasis on agricultural applications, the STW research projects are mainly executed in Departments of Biology (as indicated in the last rows of Table 1).
Tab. 1: Characterisation of the three biotechnology networks

*) Other industries, and research institutes and other organisations
TREE DIAGRAM OF EQUIVALENCE CLUSTER ANALYSIS (Ward algorithm)

NAME AND
SEQUENCE ID
---------------- DECREASING EQUIVALENCE -------->

prestabi 49 Å\  
plantzie 48 -|  
koppert 47 -|  
hosokawa 46 -|-------------------------Å\  
cbschim 45 -/ |  
pgrp 38 Å\ |  
veevoe 37 -|---------Å\ |  
cehave 36 -/ |-----Å\ |---Å\  
atodlo 24 Å\ | | |  
quest 23 -|----------/ | | |  
heineken 22 -/ | | |  
ruiter 20 Å\-----Å\ | | |  
bayer 19 -/ |Å\ |----------/  
ipo dol 21 ----Å\-| | |  
labbloe 8 ----/- |-----Å\ | | |  
pbg 42 Å\-----Å\ | | |  
nioo 41 -/ |--/ | | |  
keygene 35 --Å\---/- |----/ |Å\  
florigen 7 ---/- | | |  
eurodiag 34 Å\ | | |  
aiz 33 -|---------Å\ | | |  
solvay 32 -/ |--/ | | |  
hoogov 44 Å\-----Å\ | | |  
paques 43 -/-|-----/ | |  
amc 18 Å\----/- | | |  
azi 17 -/ | | |  
bejo 40 Å\--------Å\ | | |  
rijkzwaa 39 -/ | | |  
cprodlo 6 ----Å\Å\ |-------------------|------Å\  
have 4 -/- |---Å\ | | |  
novartis 9 ------/ | | |  
seminis 3 Å\---------Å\ | | |  
nunhems 1 -/ |--/ | | |  
zene camo 5 --Å\-----/- | | |  
plantgen 2 ---/- | | |  
inogen 16 Å\ | | |  
gistbroc 15 -/ | | |  
bloedtra 14 -| | |  
chg 13 -|---------Å\ | | |  
nizo 10 -/ |--------Å\ | | |  
akzo 12 ------/- |-------------------/- |  
tno 11 ----------------/ |  
dsm 31 Å\ | | |  
dhv 30 -/ | | |  
bio clear 29 -| | |  
vam 28 -/ | | |  
rivm 27 -/ | | |  
procha 26 -|-------------------------/ |  
meetins 25 -/  

Fig. 1: Stw Biotechnology Network 1
TREE DIAGRAM OF EQUIVALENCE CLUSTER ANALYSIS (Ward algorithm)

NAME AND SEQUENCE ID
---------------- DECREASING EQUIVALENCE -----------

npbi 23 \------------------------\aquama 22 -/ | \unisout 16 \---------------------\rivm 15 -/ | | akzo 1 ------------------------ | | fortnodg 21 \-----\ | | pharming 20 -/ |----------------\ |---\azl 12 -------/ | | rijkszwa 18 ----\\ | | have 17 ------/ \\ | | introgen 11 -------/ \\ | | azn 19 \-------/ | | isogen 7 \\-------\ | | eurodiag 6 \\-------\ \\ | | iddio 2 \\-------\ \\ | | amo 5 \\-------\ | | dsm 8 \\-------\ \\ | | gistbrog 4 \\-------\ \\ | | stowa 10 \\-------\ | | grontmij 9 \\-------\ | | boehri 14 \\-------\ | | quest 13 -/ |\=\ | | ecochermi 3 \\-------\ | |---\Fig. 2: Stw Biotechnology Network 2
Fig. 3: Stw Biotechnology Network 3

The figures in Table 1 also explain another specific attribute of the Dutch efforts in biotechnology. In the early phases of the development of biotechnology a relatively large number of Dedicated Biotechnology Firms were established in the Netherlands. Later, however, the number of biotechnology start-ups declined significantly. Table 1 shows the reason for this decline: perhaps more than elsewhere, biotechnology was very rapidly included in the activities of firms interested in the application of biotechnology. Considering the relationships of these firms with university research in The Netherlands, it can be understood that research activities elsewhere performed within DBF’s became part and parcel of these interested larger firms.

To what extent does change in the biotechnology network support Burt’s commit and survival hypotheses?

In all three subsets structural autonomous actors can be discerned (Table 2): 9 in
the first, 10 in the second and 6 in the last network. These structural autonomous actors provide the links between the various actors in the projects in each of the networks. As a result of the differences in the number of projects and the number of actors within the projects, the degree of structural autonomy of these actors is different (as indicated by their respective power and percentage of power reflected – see Table 3). Especially in the second network the differences in relative positioning of the actors are large, a consequence of the role of large chemical firms in the second network. Comparing the three networks it is also apparent that in the third network, the mean power and percentage of power reflected of both structural autonomous and non-structural autonomous actors has significantly been increased – showing the increased structuring of the intermediary context.

<table>
<thead>
<tr>
<th>NET 1</th>
<th>NET 2</th>
<th>NET 3</th>
</tr>
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<tbody>
<tr>
<td>STRUCTURAL AUTONOMOUS</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>OTHER</td>
<td>40</td>
<td>13</td>
</tr>
<tr>
<td>TOTAL</td>
<td>49</td>
<td>23</td>
</tr>
</tbody>
</table>

Tab. 2: Number Of Structural Autonomous Actors In Each Of The Networks

<table>
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<tr>
<th>NETWORK 1</th>
<th>POWER</th>
<th>POWER REFLECTED</th>
</tr>
</thead>
<tbody>
<tr>
<td>STRUCT. AUTON.</td>
<td>.463</td>
<td>13.549</td>
</tr>
<tr>
<td>OTHERS</td>
<td>.214</td>
<td>12.210</td>
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<table>
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<tr>
<th>NETWORK 2</th>
<th>POWER</th>
<th>POWER REFLECTED</th>
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<td>.547</td>
<td>18.704</td>
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<tr>
<td>OTHERS</td>
<td>.315</td>
<td>12.103</td>
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<table>
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<th>NETWORK 3</th>
<th>POWER</th>
<th>POWER REFLECTED</th>
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</thead>
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<td>STRUCT. AUTON.</td>
<td>.804</td>
<td>19.222</td>
</tr>
<tr>
<td>OTHERS</td>
<td>.537</td>
<td>17.063</td>
</tr>
</tbody>
</table>

Tab. 3: Power and percentage power reflected (interaction out that comes back) of structural autonomous and other actors in the three networks

The commit hypothesis states that structural autonomous actors are less conforming than the other actors in networks. Table 4 shows that this is also the case in the three networks in this analysis. In all three networks, the structural autonomous actors are more involved with different scientific fields in STW projects
(also outside the biotechnology field) than the other actors. Apparently the structural autonomous organisations are not confined to particular scientific fields. Does the less conforming behaviour of the structural autonomous firms also result in larger chances of survival?

<table>
<thead>
<tr>
<th></th>
<th>VARIATION</th>
<th>NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>NETWORK 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>STRUCT. AUTON.</td>
<td>6.6</td>
<td>23.6</td>
</tr>
<tr>
<td>OTHERS</td>
<td>2.5</td>
<td>5.4</td>
</tr>
<tr>
<td>NETWORK 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>STRUCT. AUTON.</td>
<td>6.1</td>
<td>16.7</td>
</tr>
<tr>
<td>OTHERS</td>
<td>1.9</td>
<td>3.3</td>
</tr>
<tr>
<td>NETWORKS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>STRUCT. AUTON.</td>
<td>4.6</td>
<td>12.2</td>
</tr>
<tr>
<td>OTHERS</td>
<td>3.9</td>
<td>11.3</td>
</tr>
</tbody>
</table>

Tab. 4: Comparison of structural autonomous actors and non-structural autonomous actors as to the involvement in different scientific fields in sw projects

The second hypothesis (Burt’s ‘survival hypothesis’) formulates a relationship of such less conforming behaviour with survival in the field. A first analysis focused on the survival of the actors in the first network (Table 5). This table reveals that a majority of the structural autonomous organisations in the first network survived in the later networks. In this respect Burt’s hypothesis is supported by the data. However, the table also shows that 10 of the non-structural autonomous organisations re-appeared in the later networks. This indicates other processes of change, not captured by Burt’s hypothesis. To further investigate this deviation of the prediction in the Burt hypothesis, subsequently the relationships between the various structural positions in the three networks were analysed (Table 6). Three conclusions can be derived from this table. In the first place, survival of the structural autonomous organisations means re-appearance in the third network (but absence in the second network). Further analysis indicates that this reveals a re-appearance of the ‘seeds-cluster’ in the third network. Secondly, some of the organisations that had a non-structural autonomous position in the first network gained a structural autonomous position in the second or third network. Moreover, some structural autonomous actors in the second and third networks were not yet present in the first network.
Tab. 5: Structural autonomy in network 1 and survival

<table>
<thead>
<tr>
<th></th>
<th>SURVIVAL</th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>YES</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>STRUCTURAL AUTONOMOUS IN NETWORK 1</td>
<td>6</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>NOT STRUCTURAL AUTONOMOUS IN NETWORK 1</td>
<td>10</td>
<td>30</td>
<td></td>
</tr>
</tbody>
</table>

Tab. 6: Structural autonomy in all three networks and survival

These conclusions indicate the effects of other variables (which we will deal with later), but also point to an omission in the Burt analysis. Burt’s notion of survival in networks does not include the possibility of change as a consequence of organisations developing structural autonomy (as well as the entrance of new organisations that develop structural autonomous positions in later stages of the development of networks). A more adequate theory of change in networks should include these possibilities (as the analysis in this case indicates).

Hypothesis 3 and 4 state the effects of other variables on the processes of change in networks. In the case of the networks in this case, located in the intermediary context between the science system and the economy, one would expect effects of the extent to which the networks are differentiated from either one of these contexts.
Differentiation, as indicated earlier, concerns the cognitive patterns (and changes in these patterns) as a result of the relationships with the two respective environments. Dependence measures the extent to which these cognitive patterns are socially supported.

The most elaborate analysis of differentiation would entail a precise indication of the various research problems within the subsequent networks. As a proxy of the research problem networks and their development, we have focused on the extent to which the biotechnology networks were characterised by patterns, either from the scientific context (the extent to which the actors were involved in particular scientific fields) or from the economic context (the extent to which the actors were involved in particular industries). The figures in Table 1 already showed that most projects are formulated within the biological sciences (chemistry is the only other scientific field with a relatively high frequency). Furthermore, the involved firms for a large part represent a large variety of industries, with only agribusiness as a major context of application.

Comparing the three consecutive networks in this respect shows that biology (and agribusiness) were more important in the first and third network and chemistry (and firms from the chemical industry) more important in the second network.

However, particular combinations of scientific fields and industries would only indicate specific clusters in the various networks when organisations were only present in particular combinations of scientific fields and industries, and not in others.

In general, the networks do not show such specific configurations – except in the case of the seeds firms, combined with research organisations and universities (especially the Agricultural University of Wageningen) in the first and third network.

To analyse the attributes of the configurations of scientific fields and industries, we focused on two specific networks, i.e. the networks in biology and chemistry (the frequencies of the other scientific fields was too low to enable such analyses). If differentiation occurs in these networks, scientific fields should be characterised by interest from particular industries (and this interest should not overlap comparing the networks). Table 7 shows that in the case of the biology network, firms from agribusiness, especially seeds producing firms have a central position. In the case of the chemistry network firms from the chemical industry are (self-evidently) more significantly present (as shown in the table). But in the latter case it is surprising to note the dominance of research organisations rather than firms in the network. A further analysis of the research problem networks would probably show that the distance between research and market in the latter network is larger than in the case of the plant – related research networks.
Moreover, comparing the actors in the two networks shows that approximately 50 percent of the actors in the (smaller) chemistry network also are present in the biology network. This equally applies to structural autonomous and to non-structural autonomous organisations. We can thus conclude that the extent of differentiation of the biotechnology intermediary context from the two institutional contexts is rather low (with one major exception: the relationship between biotechnological research and the seeds producing firms). And, hence we have to conclude that support for the third hypothesis is lacking. Instead, the intermediary context is related to various combinations of scientific fields and industries, except for the specific cluster of firms and research organisations around the Agricultural University of Wageningen.

This result of the analysis also has consequences for the fourth hypothesis: the behaviour of structural autonomous firms within the specific configurations. In this respect two different tendencies can be discerned in the material. In the one specific (seeds related) cluster, the structural autonomous firms do not show much variation in their interest in biotechnological research. They are interested in particular research results, and not in other. However, in the case of the (though less visible) cluster of chemical firms in the chemistry network the opposite behaviour can be discerned. In the latter case the structural autonomous firms are interested in a variety of research results, resulting in their involvement in various different biotechnology projects.

Consequently, biotechnology in The Netherlands shows a clear focus on agricultural applications, but far less focus in other fields, such as health- and environmental related research.

In this respect the intermediary context is still rather unstable. This is also most
recently exemplified by major mergers between firms and between research organisations in this context. The separate cluster in the agribusiness around the Agricultural University Wageningen has recently dramatically changed, as the DLO research institutes have been included in the university context. Several mergers have in the recent past occurred between firms in our networks (e.g. DSM and GistBrocades; Unilever and Quest). All these activities show once more the rapid change occurring in this context.

6. Discussion

The objective of this paper was to conceptualise the intermediary sector in between the institutional contexts of academic and industrial research, and especially to indicate the determinants of change of this intermediary sector.

The starting point of the analysis was Burt’s two hypotheses: respectively stating the relationship between structural autonomy and commitment to the ‘scheme’ of a particular context and the resulting survival of organisations. Burt has tested his hypotheses in the context of economic markets. In this case differentiation of the context is maximal and dependence is minimal: firms compete with one another in a situation in which consensus exists among participants on the market schedule accepted. Markets thus become arenas in which ordering between actors occurs according to accepted criteria and in which dependence on social factors is minimal.

In the case of the research sector studied here, differentiation is less clear and hence the possibility of other effects on survival as a result of the influence of social factors. We pointed to two notions of embeddedness as indicated by White: the extent of differentiation and extent of dependence.

The research showed that, as expected, Burt’s hypotheses only partly were supported by the data: other factors, i.e. the effects on survival of the two surrounding institutional contexts could be discerned.

Still the study also showed some general consequences for Burt’s view on processes of change in networks. Actors can also become structural autonomous in the developmental processes of networks, as well as new structural autonomous actors can enter the network in a later stage.

The conceptualisation of the research field of biotechnology in terms of changing network relationships as presented here is limited by the nature of the data. The three subsequent networks only encompass a period of approximately 10 years. Consequently, long-term developments can not be captured by this data set. Moreover, the limitation of the analysis to only one example of the intermediary sector of strategic scientific research leads to questions regarding the generalizability of these results for other similar examples in the innovation system.

Further research should therefore entail: (a) the comparison of the results in this field of science to relationships around other fields of strategic science; (b) the multilevel analysis of the totality of the innovation system and (c) the comparison of
the structure of the intermediary sector of this particular part of the innovation system with similar examples of this intermediary in other parts of the innovation system.

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