



HAL
open science

Policy Measures and Effects in the Different Phases of the Cluster Life-Cycle

Thomas Brenner, Charlotte Schlump

► **To cite this version:**

Thomas Brenner, Charlotte Schlump. Policy Measures and Effects in the Different Phases of the Cluster Life-Cycle. *Regional Studies*, 2011, pp.1. 10.1080/00343404.2010.529116 . hal-00658168

HAL Id: hal-00658168

<https://hal.science/hal-00658168v1>

Submitted on 10 Jan 2012

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Policy Measures and Effects in the Different Phases of the Cluster Life-Cycle

Journal:	<i>Regional Studies</i>
Manuscript ID:	CRES-2009-0137.R1
Manuscript Type:	Main Section
JEL codes:	R12 - Size and Spatial Distributions of Regional Economic Activity < R1 - General Regional Economics < R - Urban, Rural, and Regional Economics, C51 - Model Construction and Estimation < C5 - Econometric Modeling < C - Mathematical and Quantitative Methods, C53 - Forecasting and Other Model Applications < C5 - Econometric Modeling < C - Mathematical and Quantitative Methods
Keywords:	cluster, life-cycle, mathematical model

SCHOLARONE™
Manuscripts

1
2 Policy Measures and Their Effects in the Different Phases of the Cluster Life-Cycle
3
4
5
6
7

8 Thomas Brenner and Charlotte Schlump
9

10
11
12
13
14
15
16
17
18
19 Current address:
20

21
22 Philipps-University Marburg, Department of Geography, Deutschhausstr. 10, 35032
23

24 Marburg, Germany
25

26
27 thomas.brenner@staff.uni-marburg.de, tel. +49-6421-2824211, fax. +49-6421-2828950
28

29
30 schlump@staff.uni-marburg.de, tel. +49-6421-2824409, fax. +49-6421-2828950
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

(Received May 2009; in revised form June 2010)

ABSTRACT

In recent years, policy measures have frequently been applied to clusters. This paper analyses whether different types policy measures should be applied in different stages of the cluster life-cycle. Two approaches are used to obtain answers to this question. First, we gather insights from existing literature on policy measures and their evaluation. Second, we set up a mathematical model in order to examine the effects of various policy measures in the different life-cycle phases. We find that the adequate kind of policy measures depend on the cluster's current stage in its life-cycle.

Keywords: cluster, life-cycle, policy

JEL: C50, O30, R11, R58

Abstract German:

Die Förderung von Clustern hat in den letzten Jahren in der Politik viel Aufmerksamkeit erhalten. Dieser Artikel untersucht mit zwei verschiedenen Ansätzen, ob in verschiedenen Phasen des Clusterlebenszyklus unterschiedliche Fördermaßnahmen geeignet sind. Zunächst werden die in der Literatur vorhandenen Ergebnisse und Erkenntnisse über Fördermaßnahmen und deren Wirksamkeit zusammengetragen. In einem zweiten Schritt wird ein mathematisches Modell der Clusterentwicklung aufgestellt. Mit Hilfe dieses Modells werden die Effekte der verschiedenen Fördermaßnahmen in den unterschiedlichen Phasen des Clusterlebenszyklus analysiert. Dabei können wir zeigen, dass eine adäquate Förderung von Clustern tatsächlich von der aktuellen Phase im Lebenszyklus abhängt.

I. Introduction

Currently, there has been a growing interest in generating and supporting local clusters.

While designing policy programs, policy makers often do not take into account the different phases of the cluster life-cycle. The same measures are applied to all supported local clusters within a program. Hence, if the choice of clusters within such programs does not implicitly restrict the applied measure to clusters in the same life-cycle phase, no differentiation between cluster life-cycle phases is made.

This is partly caused by the fact that the scientific literature rarely provides recommendations on how to select adequate policy measures in order to support clusters throughout the different stages of the cluster life-cycle. While there does exist sufficient literature that which deals with the cluster life-cycle as such, the connection between life-cycle theory and policy has been mainly ignored. This paper intends to fill part of this gap.

There is an ongoing debate about the effectiveness and usefulness of cluster policy. While some authors assume governmental support only to have small influence on clusters' emerge or competitiveness (e.g. VAN DER LINDE, 2003), others tend to see great potential in governmental intervention. As most of the policy activities on clusters have been conducted quite recent, the measures' impact still needs time to show up and to be evaluated (ENRIGHT, 2003). Furthermore, we expect that different policy measures vary in their effectiveness over the cluster life-cycle since mechanisms and processes relevant within clusters change over time. Economically successful and competitive clusters usually do not need any policy support, whereas certain measures might be conducive to the functioning of a cluster during its emergence and maturity phase in particular (HOSPERS and BEUGELSDIJK, 2002). Thus, it is not easy to determine what kind of policy measures really affect cluster development as the needs and evolution of clusters vary between the different types and stages of the cluster's life-cycle.

Different policy measures are examined in varying depths in the literature. Universities and

1
2 research institutes are seen as major driving forces of cluster formation. Hence, their
3
4 relevance in different stages of the cluster development is frequently discussed
5
6 (HUGGINS, 2008; MARTIN and SUNLEY, 2003 among others). Other aspects of policy
7
8 involvement, such as the support of local cooperation, are rarely addressed in the context
9
10 of the cluster life-cycle. Furthermore, the discussion is entirely theoretical. There is a lack
11
12 of empirical comparisons and mathematical approaches evaluating the different effects of
13
14 policy measures in the stages of the cluster life-cycle.
15
16
17

18
19 Our approach differs from the existing literature in various aspects. First, we develop a
20
21 mathematical model that describes the dynamics of clustering. We use this model to
22
23 analyse the impact of policy measures in the different stages of the cluster life-cycle.
24
25
26 Second, we use empirical data to set up and calibrate the model, i.e. the mechanisms
27
28 causing cluster formation are modelled in line with empirical knowledge in order to make
29
30 the implications of the model reliable. We also estimate the parameters of the model
31
32 empirically in order to make the magnitude of effects reliable. Third, we use knowledge
33
34 from the literature to determine the changes of the model's parameters over the cluster
35
36 life-cycle. This leads to reliable implications on the effectiveness of policy along the cluster
37
38 life-cycle. This leads to reliable implications on the effectiveness of policy along the cluster
39
40 life-cycle.
41
42

43
44 This paper aims at a better understanding of the impact of policy measures on the
45
46 development of local clusters in general and of the relevance of the measures' timing in
47
48 particular. The key contribution of this paper to the literature on cluster life-cycles is the
49
50 answer to the question of how policy measures should vary along the different stages of
51
52 the cluster life-cycle. The results allow us to advice policy makers on adequate policy
53
54 measures. We believe that policy activities should take into account the different stage of
55
56 the cluster life-cycle.
57
58

59
60 The paper proceeds as follows. In Section II we reflect on the theory of the cluster life-
cycle and the existing empirical and theoretical knowledge about policy measures and

1
2 their impact. The mathematical model is set up in Section III. In Section IV the general
3
4 characteristics of this model are analysed first. Successively, the impacts of the various
5
6 policy measures are examined. Section V concludes the paper.
7
8
9

10 11 12 II. Theory 13

14
15 There is a huge literature on clusters and a small but developing literature on the cluster
16
17 life-cycle. This literature describes the development of clusters in time. Various theories
18
19 and concepts on cluster development exist. They build their arguments on different ideas,
20
21 theories, and empirical observations. Nevertheless, there is quite an overlap in the
22
23 predictions. In the following, we discuss the basic arguments and predictions about the
24
25 cluster life-cycle and detect a number of common features.
26
27
28

29
30 Furthermore, different policy measures that are applied to clusters are analyzed and
31
32 grouped. In this context we focus on our main question discussing the effectiveness of
33
34 different policy measures along the cluster life-cycle. There is an ongoing debate about the
35
36 effectiveness of cluster policy in general. A quantitative survey of all possible cluster
37
38 policies and a comparison of their impacts are still missing (KIESE, 2008). Quite often,
39
40 policy or public action is seen as an inevitable and internal element of clusters (BORRÁS
41
42 and TSAGDIS, 2008). This shows the implicitness of some policy intervention and the
43
44 difficulty to estimate the overall importance of policy for the enhancement of cluster
45
46 capabilities and competitiveness. Considering all knowledge about clusters and policy
47
48 involvement, especially knowledge gathered in case studies (see BRENNER and MÜHLIG,
49
50 2007) we come to the conclusion that policy measures at least have a potential impact on
51
52 the development of clusters. In this paper, we do not focus on the question of whether
53
54 there are policy impacts, but on the question of how the timing and choice of measures
55
56 can help to make these more effective.
57
58
59
60

1
2 Therefore, we start with a description of the cluster life-cycle (Section II.1). Then we reflect
3
4 on the discussion about the effectiveness of cluster policy (Section II.2). Although we do
5
6 not intend to and cannot answer the question of whether cluster policy is effective, this
7
8 discussion shows the importance of further analyses about the choice of the adequate
9
10 measures. The various potential measures are discussed in detail in Section II.3.
11
12
13

14 15 16 17 II.1 The cluster life-cycle 18

19
20 The various approaches on the cluster life-cycle more or less seem to agree about the
21
22 existence of three distinct phases: an initial or development stage, an expansion stage, in
23
24 which the cluster forces that are usually discussed in the literature are active, and a
25
26 mature stage. The last phase sometimes is combined with the option of decline
27
28 (MAGGIONI, 2004). Further, the phase of decline sometimes is defined as a fourth stage,
29
30 which might also be characterised by a transformation or a decline of the cluster (VAN
31
32 KLINK and DE LANGEN, 2001 and BRENNER, 2001). Although there is a fourth stage, we
33
34 only include the first three stages in our analysis since the mechanisms and processes
35
36 underlying the fourth stage differ crucially, which would complicate the analysis of the
37
38 model.
39
40
41
42

43
44 The cluster life-cycle concept has developed out of the concepts of the product and
45
46 industry life-cycle. Nevertheless, cluster and industry or firm life-cycles are not the same.
47
48 They have developed differently over time and only show some parallels (MENZEL and
49
50 FORNAHL, 2007). However, as the industry life-cycle is connected with agglomeration
51
52 effects and thus the formation of clusters, there is a linkage between the two concepts
53
54 (AUDRETSCH and FELDMAN, 1996). BRENNER (2001 and 2008) argues that there is a
55
56 causal relation between the industrial life-cycle and the life-cycle of clusters in this industry.
57
58 Usually, clusters emerge during the initial stage of the corresponding industry life-cycle. A
59
60 cluster's expansion phase usually goes together with the expansion phase of the market

1
2 for the respective products. If an industry is mature and the markets satiated and very
3
4 competitive, clusters usually stabilise and show little dynamics.
5
6
7
8
9

10 *Initial or development stage*

11
12 In the initial stage of the cluster life-cycle we are able to detect the emergence of some
13
14 places in which the respective industry becomes concentrated. When a new industry or
15
16 technology emerges, the first firms active in the emerging field are often scattered in space
17
18 (KLEPPER, 2007). While the industry is growing, more firms appear and start to expand.
19
20 There are certain forces that cause growth to be stronger in a few regions. Spin-offs can
21
22 be seen as one of the mechanisms causing the geographic concentration of an industry
23
24 (ARTHUR, 1994; KLEPPER, 2007). MENZEL and FORNAHL (2007) argue that in the
25
26 initial stage only little interaction between firms in a region does take place; they see spin-
27
28 offs and the interaction between firms and universities as well as firms and public research
29
30 institutes as the main driving forces in this stage. Furthermore, local conditions and policy
31
32 have an influence on the development of the cluster. On the contrary, BRUSCO (1990)
33
34 argues that in the very beginning of the development of industrial districts government
35
36 intervention is hardly feasible as in this stage it is impossible to identify clusters statistically
37
38 and thus to apply appropriate policy measures. He argues that only later, when industrial
39
40 districts are more established, there is a need for intervention and policy measures.
41
42
43
44
45
46
47
48

49 In the initial phase of the cluster life-cycle it is important that a critical mass of economic
50
51 activity is reached in the region (ARTHUR, 1994; BRENNER, 2001). Local conditions as
52
53 well as the kind and number of firms located in the region determine whether this critical
54
55 mass is reached or not. Especially the founding of firms that become central for the region
56
57 can be seen as a random event that contributes to the development of the cluster crucially
58
59 (PORTER, 1998b). BOSCHMA and WENTING (2007) show that the presence of related
60
industries also plays an important role for the further growth of clusters.

1
2 To sum up, in the initial stage start-ups and spin-offs are of great importance but also the
3
4 parent firm or organization may play an strong role. Furthermore, local conditions,
5
6 especially the presence of related industries, universities, and public research seem to
7
8 contribute to the development of clusters. This implies that all variables and parameters
9
10 related to firm foundation, the presence of industries, universities and public research
11
12 should be high in this early phase of the cluster life-cycle. According to BRENNER (2001)
13
14 and MENZEL and FORNAHL (2007) the industry life-cycle is in its initial stage, too, so that
15
16 the market situation can be expected to start improving.
17
18
19
20
21
22
23

24 *Expansion stage*

25
26
27 In the cluster's expansion stage, the market for the respective technology or industry
28
29 increases tremendously and so do the number of firms, employment and other related
30
31 activities. In this phase, Marshall's agglomeration economies become influential
32
33 (MAGGIONI, 2004). Marshall argues that the local firm population benefits from a common
34
35 labour market, synergies and interaction between firms and the development of service
36
37 and supplier firms in the region. Part of this argument is based on spillovers between firms
38
39 that seem to contribute to local growth, especially in 'new' industries (GLAESER et al.
40
41 1992, HENDERSON et al. 1995). These spillovers do not only occur between firms of the
42
43 same industry, as argued by Marshall, but also between firms from different industries. The
44
45 latter is part of the so-called Jacob's externalities. This implies that diversity becomes an
46
47 important aspect in the development.
48
49
50
51

52
53 The networking activities grow and become very important in the expansion phase, while
54
55 the cluster becomes more focused (MENZEL and FORNAHL, 2007). Furthermore, we
56
57 know from the industrial life-cycle literature that innovation activities are very important in
58
59 this phase (KLEPPER, 1997). This seems to apply for the cluster life-cycle as well.
60

1
2 To sum up, in the expansion stage regional self-reinforcing processes become crucial for
3
4 the developments in the region. These processes are mainly based on direct interaction
5
6 between firms and their surroundings. Cooperation, networks, and innovations are very
7
8 important in this phase. Start-ups are still important, although slightly losing importance.
9
10 Hence, all variables and parameters related to innovation and interaction between regional
11
12 actors can be expected to have very high values, although those connected to start-up
13
14 activities still have some importance. The market situation is very profitable in this phase.
15
16
17
18
19
20
21

22 *Mature stage*

23
24 In the mature stage of the cluster, market growth has slowed down (BRENNER, 2001).
25
26 Market development has stabilised and the situation has reached a kind of equilibrium
27
28 (MENZEL and FORNAHL, 2007). In the industry life-cycle, the system passes through a
29
30 shake-out phase (KLEPPER, 1997). Start-ups do not play a role any more. We still find
31
32 some regional self-reinforcing forces and firms might still benefit from being located in a
33
34 cluster (as the finding in PORTER, 2003 suggest). However, there is also empirical
35
36 evidence suggesting that firms do not benefit from being located in a cluster in later stages
37
38 of the cluster life-cycle (AUDRETSCH and FELDMAN, 1996). However, regional
39
40 networking and cooperation activities are well established in this stage (MENZEL and
41
42 FORNAHL, 2007).
43
44
45
46
47
48

49 To sum up, start-ups play no role in the mature stage of the cluster life-cycle anymore.
50
51 Most cluster forces are only of some importance, while regional networking and
52
53 cooperation activities are main features of well-established clusters. Hence, all variables
54
55 and parameters connected with networking should be high, while most other variables and
56
57 parameters are low or medium.
58
59
60

Declining stage

Compared to the mature stage, we do not find much difference to the cluster's situation in the declining stage. This might be a reason why these two stages are sometimes not distinguished from each other. The main difference is that in the declining stage the market for the products produced within the cluster decreases strongly. Hence, the market situation becomes very difficult. Therefore, the cluster is forced to decline or to transform itself in order to open up new market possibilities.

It is difficult to study the declining stage with the model developed below. Therefore, we focus our analysis on the first three stages of the cluster life-cycle.

Transition between stages

In their development, clusters do not jump from one stage to the other. Instead, they usually transform slowly to the next stage. This transformation can be seen as a transition phases. As clusters consist of a huge amount of different firms and institutions, these actors are not necessarily in exactly the same stage of development at any point in time. Therefore, some protagonists may stay in a certain life-cycle stage whereas others already moved further on. We define the cluster life-cycle phase as the phase in which the focal firms are at each point in time (MENZEL and FORNAHL, 2007).

II.2 Cluster policy and policy considerations

Nowadays, nearly all national and regional authorities apply some kind of cluster policy measures. As clusters are generally said to provide advantages to regions and their firms, the overall aim of cluster policy is to enhance the economic performance of regions and nations (EUROPEAN COMMISSION, 2008; RAINES, 2000). Cluster policy can be seen as "a set of policy interventions aiming at strengthening existing clusters or facilitating the

1
2 emergence of new ones” (EUROPEAN COMMISSION, 2008, p.28). There is an ongoing
3
4 debate whether cluster policy really is a new policy field or just old wine in new skins. The
5
6 seminal works of PORTER (1990, 1998a, 1998b) build the theoretical background for most
7
8 of the measures promoting clusters in the recent years but there are also cluster-related
9
10 policies with different background. Most of these ideas have been integrated in industrial
11
12 policy in developed countries in the 1990s focusing on collaborative elements, networks,
13
14 and regional developments. These cluster-related measures complement traditional sector
15
16 policies by adding a spatial focus (BORRÁS and TSAGDIS, 2008; KOSCHATZKY, 2005;
17
18 KIESE, 2008). The case study literature shows that not only policies supporting cluster
19
20 development had an impact on cluster, but also policies with no intended spatial focus. For
21
22 example, policy measures with unintended spatial effects play an important role for so
23
24 called high-tech regions, in the early stages of development in particular (STERNBERG,
25
26 2003).
27
28
29
30
31
32

33 The important question is what role does cluster policy play for the development of
34
35 clusters? Most of the pros in favour of measures supporting the development of clusters
36
37 can be summed under the concept of systemic and market failure. In addition, the wish for
38
39 a functioning cluster may be a reason for policy intervention. However, government failures
40
41 may also lead to a misguided development of the cluster (ROELANDT and DEN HERTOOG,
42
43 1999).
44
45
46
47

48 Thus, in the past decades policies have become more oriented towards the regional level
49
50 (KOSCHATZKY, 2005). However, they still lack a focus on the different needs of clusters
51
52 during the life-cycle phases. Cluster policy measures should be adapted to the cultural and
53
54 political circumstances as well as the cluster’s current life-cycle stage (MASKELL and
55
56 KEBIR, 2006). Blue prints or “one-fits-all”-approaches usually do not lead to the expected
57
58 results. Nevertheless, the adaptation to regional and cluster characteristics, needs and
59
60 weaknesses is not always successfully implemented (EUROPEAN COMMISSION, 2008).

1
2 Frequently, policy makers do only consider parts of the cluster concepts when designing
3 cluster policy measures. This partial implementation leaves important connections
4 between the elements of the cluster concept outside the focus (LUNDEQUIST and
5 POWER, 2002). Ignoring the local cultural, historical, and industrial differences, policies
6 run the risk of simply copying other successful clusters.
7
8

9
10
11
12
13
14 As mentioned above, the government's impact on the success and competitiveness of
15 clusters is said to be marginal. In a meta-study by VAN DER LINDE (2003) it is shown that
16 there is only minor influence of governmental support on the survival of clusters.
17
18

19
20
21 Furthermore, this meta-study finds that the number of clusters established by the state is
22 small (although such cases exist). Other concerns about the efficiency of cluster policies
23 relate to the small number of small and medium enterprises that participate in the
24 measures and programs. In addition, many policy programs do not identify market failures.
25
26

27
28
29
30
31 As a consequence, policy measures sometimes tend not to have a real focus. Another
32 challenge is the heterogeneous cluster identification. Cluster policies may be initiated with
33 no real cluster present (HOSPERS and BEUGELDIJK, 2002). This might be one reason
34 explaining the lack of positive results of governmental cluster policies. Additionally, causal
35 relations between the different factors that can be influenced "cannot be determined on the
36 basis of theoretical or philosophical arguments" (JAFFE, 1999, p. 64) but need to be
37 addressed empirically. However, causality may be reversed because highly innovative
38 firms (regions) face less difficulties acquiring R&D funds (see, e.g. BUSOM, 1999).
39
40
41 Furthermore, time lags need to be considered when analyzing outcomes of policy
42 measures (FRITSCH and SLAVTCHEV, 2005).
43
44

45
46
47
48
49
50
51
52
53
54 To sum up, on the one hand, the literature provides arguments that suggest (cluster)
55 policies to be of little importance or to take a marginal, indirect and long-term role, e.g. it is
56 said that policy measures seem to be superfluous because cluster dynamics should make
57 intervention redundant (MASKELL and KEBIR, 2006). On the other hand, the literature
58
59
60

1
2 provides arguments stressing the impact of cluster policy. In case studies, policy is often
3
4 said to play an important role (BRENNER and MÜHLIG, 2007).
5

6
7 It seems as if the way of policy implementation is crucial for the measure's success. There
8
9 are many obstacles cluster-related policy has to face. One obstacle we would like to
10
11 discuss in this paper is the question of how to adjust measures to the needs of the
12
13 different stages of the cluster life-cycle. In the context of SME policies, a similar topic
14
15 arises: measures have to be adapted to differences in the way in which innovations are
16
17 generated and in the importance of innovations (SMALLBONE et al., 2003). In Section II.1
18
19 we argue that the stages of the cluster life-cycle differ strongly with respect to the problems
20
21 and needs that can be addressed by policy. This fact seems to be neglected in policy
22
23 approaches quite frequently. In Europe, only 36 of 69 national cluster programs have a
24
25 special focus on clusters in a certain stage of the life-cycle, mainly on the emerging and
26
27 embryonic phase (EUROPEAN COMMISSION, 2008).
28
29
30
31
32
33
34
35

36 II.3 Measures of cluster policy 37

38
39 Cluster policy can take many different forms. Above we argued that it is important to find
40
41 the form which fits the characteristics of the cluster the policy aims at. One of these
42
43 characteristics is the stage in the cluster life-cycle. In the following, we focus on the
44
45 various measures that are applied within the framework of cluster policy. We present the
46
47 instruments and their evaluations if available. We would like to examine the way these
48
49 instruments work in order to include them in our mathematical model adequately.
50
51

52
53 Furthermore, we would like to review the existing knowledge about the instruments'
54
55 effectiveness, although there seems to be little knowledge available.
56
57

58
59 Possible measures to support cluster development are direct and indirect financial support,
60
start-up support, aid for administration, networks and cooperation as well as general
assistance for cluster activities. We divide these measures into six categories, bearing in

1
2 mind the measures' impact during the different stages of the cluster life-cycle. These
3
4 categories are education, public research, R&D support and influencing the innovation
5
6 culture, start-up support, network organisation and cooperation support as well as policy
7
8 measures pointing at the amendment of the infrastructure and local conditions. Most of the
9
10 time, these measures are implemented by regional or national public authorities. In some
11
12 cases, however, cluster initiatives are involved. These initiatives aim at similar objectives
13
14 as "usual" policies (SÖLVELL et al., 2003).
15
16
17
18
19
20
21

22 *Education*

23
24 In the remainder of this paper, cluster policy measures aiming at the amendment of the
25
26 cluster's knowledge base and skills are subsumed under the label "Education". As
27
28 knowledge is seen as one of the driving forces of cluster development, "Education" refers
29
30 to measures aiming at human capital formation (AUDRETSCH and LEHMANN, 2006).
31
32 These measures, often applied indirectly, help to "create an environment conducive to
33
34 growth" (CHESHIRE, 2003, p. 332). Policy measures focusing on knowledge creation and
35
36 skills can be long-term or short-term oriented. Long-term measures address the
37
38 permanent local conditions, e.g. the set-up of new universities, departments or research
39
40 institutes. As these set-ups usually involve high investments, they are often implemented in
41
42 a later stage of the cluster life-cycle, possibly in the maturation stage. However, the timing
43
44 for such measures is less important than of others (BRENNER, 2008; DTI, 2004).
45
46
47
48
49
50
51 Short-term measures address local conditions that change in time, e.g. the specific
52
53 research and lecturing topics at local universities or specific education programs in a
54
55 region. These measures include specifically qualified education, skill training and staff
56
57 qualification to improve the knowledge base and skills of the different cluster members in
58
59 the respective technological field. Furthermore, they are meant to improve the local actors'
60
management skills.

1
2 The development of skills is especially important for the preservation of the cluster in the
3
4 initial and emerging stages (DTI, 2004). In addition, MARTIN and SUNLEY (2003) point
5
6 out the importance of linking the cluster to universities in order to profit from the
7
8 university's research and education fitting the cluster's technological focus. HUGGINS
9
10 (2008) highlights the importance of training and education not only in the development
11
12 phases of the cluster. Even later, when the cluster is already in a mature stage, a well-
13
14 educated workforce and human capital is crucial in order to keep up the cluster's
15
16 innovative level and avoid a possible decline or lock-in. In this phase, a high level of
17
18 specialization seems to gain more importance. In Sweden for example, financial support
19
20 for training, seminars and the exchange of experience is given. The specialization of the
21
22 cluster's workforce should be promoted in order to increase the economic development in
23
24 the winning regions (DINNETZ, 2007). Another example is the Life Science Austria Cluster
25
26 in the Vienna region, which is a cluster in an emerging stage. The measures taken to
27
28 promote the education of the local workforce are seminars and business plan
29
30 competitions. In addition, vocational training in the field of business administration for
31
32 natural scientists, engineers and physicians working in the life sciences is an important
33
34 measure in these early stages of the life-cycle, because the formation of new companies
35
36 and start-ups plays an enormous role in these stages. Up to now, these measures have
37
38 not been evaluated (ENICHLMAIR and OBERHOLZNER, 2007).
39
40
41
42
43
44
45
46

47 To sum up, education plays an important role in cluster development. This seems to hold
48
49 for all stages of the cluster life-cycle, so that policy measures that improve education
50
51 should not focus on any stage.
52
53
54
55

56 57 *Public research*

58 Another important aspect which is partly connected with education is "Public research".
59
60 Public research plays an important role in cluster emergence as it provides specialized

1
2 knowledge and service (PORTER, 1990). But also in a more mature stage, this knowledge
3
4 is crucial to prevent the cluster from a possible decline. Besides providing knowledge,
5
6 public research is relevant for the provision and training of a qualified work-force.
7
8

9
10 Likewise, researchers working at research institutes are potential entrepreneurs as they
11
12 may found their own company with ideas stemming from the cluster related research
13
14 (PORTER, 1998b). Therefore, policy makers often regard the implementation of public
15
16 research as an appropriate measure to promote the economic development of clusters.
17
18 The establishment of a new research institute is less frequent than the support of research
19
20 collaborations, a new focus in public research or money for specific projects and additional
21
22 scientists. Possible measures to reach this aim are, for instance, the establishment of
23
24 relevant laboratories. Especially in the cluster's initial and emerging phase these may be of
25
26 relevance. To assure a high product quality right from the beginning, laboratories may be
27
28 employed for quality verification and certification. But also the development and testing of
29
30 new products may be sourced out to a specific research institute (FOUNDATION FOR
31
32 ENTREPRENEURSHIP DEVELOPMENT, 2007). Another possible measure is the
33
34 implementation of joint industry-research centres that support collaborations between firms
35
36 and public research institutions. This can be helpful during all stages of the cluster life-
37
38 cycle (ANDERSSON et al., 2004).
39
40
41
42
43
44

45 To sum up, public research is often a crucial factor in the development of clusters.

46 Although effects can be expected for all stages of the cluster life-cycle, most arguments
47
48 focus on the earlier stages.
49
50
51

52 53 54 55 56 *Supporting R&D and innovation culture* 57

58 The support of public research has to be distinguished from R&D support and influence on
59
60 the local innovation culture as those focus on the firm level. The support of R&D does not

1
2 need to be connected to already existing research institutes but can be implemented in
3
4 firms only. The innovation culture of a firm may be influenced and thus the innovation
5
6 culture of a whole region. A well-known example for this is Sophia Antipolis where local
7
8 and national authorities initiated innovation service activities and thus created an
9
10 innovative milieu (LONGHI, 1999). This development is mainly important in the early
11
12 stages of the cluster life-cycle where, on average, the innovation activity is more relevant
13
14 than in the mature stage. Normally, the impact of innovations decreases with the cluster's
15
16 maturation. Policy should aim at supporting the cluster's innovativeness by combining key
17
18 players and qualifications (FROMHOLD-EISEBITH and FROMHOLD, 2005). Formal
19
20 institutional structures like the establishment of science parks or incubators may be
21
22 influenced or established by policy and may help to improve the innovation culture and
23
24 processes (BATHELT and DEWALD, 2008).
25
26
27
28
29
30

31 In the Cypriot cluster, for instance, policy put emphasis on these measures. In the
32
33 cluster's initial stage, in particular, they supported innovations on the production level in
34
35 order to develop an innovation culture in the region. The program offers financial support
36
37 to the foremost small and medium sized companies in the targeted clusters in the
38
39 manufacturing and service sectors. Since the program in Cyprus was started in 2007,
40
41 there is no evaluation available, yet (PAPADOPOULOS, 2007).
42
43
44

45 In Germany, the BioRegio-Contest aimed at the overall goal to become one of Europe's
46
47 largest agglomeration of biotechnology firms. The focus was to enlarge the application-
48
49 oriented research in biotechnology and to turn the scientific results into industrial activity
50
51 by giving financial support to the different projects (HAUSER, 2007). Another example is
52
53 the South Denmark region with its cluster policy focusing on emerging and developing
54
55 clusters. The government finances screening activities that should help firms of emerging
56
57 clusters to address the technological needs in their field of activity. However, access to
58
59 new technologies is also a measure implemented in more mature clusters when it
60

1
2 becomes important to gather momentum to prevent the cluster from a possible decline. As
3
4 the program was launched in 2007 there is no evaluation available, yet (SCHOU, 2007).
5
6

7 To sum up, the support of R&D activities of firms is mainly assumed to be important in the
8
9 early stages of the cluster life-cycle. Most of these policy measures address young or
10
11 emerging clusters. However, it might also be helpful to prevent the decline of existing
12
13 clusters.
14
15

16 17 18 19 20 *Support of start-ups* 21

22
23 As mentioned above, the support of start-up companies is highly connected with cluster
24
25 policies since the development of a local firm base is a crucial aspect contributing to the
26
27 emergence of local clusters. During a phase of technology shift leading to the
28
29 establishment of networks and structures, start-up companies as well as support
30
31 organizations are of utmost importance. HUGGINS (2008) argues that in the development
32
33 phase of knowledge clusters networks and strong ties can lead to a higher number of
34
35 entrepreneurs and start-up companies in the respective cluster. In later stages, when the
36
37 cluster constitutes a functioning entrepreneurial base, second-tier start-ups, spin-offs and
38
39 venture capitalists are needed to sustain the cluster development (WOLFE and GERTLER,
40
41 2006).
42
43
44
45

46
47 Therefore, the support and enhancement of start-up companies often plays a significant
48
49 role in cluster policies. There seems to be no significant difference between the life-cycle
50
51 phases as measures are applied in the embryonic, emerging and mature phase. The
52
53 improvement of local conditions through service firms and other supporting measures
54
55 should also strengthen the potential for start-ups and spin-offs. In Germany, the BioRegio
56
57 contest can be taken as an example which aims at enlarging the number of start-up
58
59 companies in the biotechnology sector through offering financial support. As stated above,
60

1
2 the ambition was to turn state of the art research knowledge into production activities. The
3
4 evaluation conducted by the Kiel Institute for the World Economy revealed a positive
5
6 impact of the BioRegio program, especially on the development of the number of firms. All
7
8 in all, 600 new companies have been founded; thereof more than 340 in the biomedical
9
10 sector (HAUSER, 2007).
11
12

13
14 Likewise, the British government tries to enhance the number of start-up firms in the
15
16 biotechnology sector by building biotechnology incubators, grow-on facilities and science
17
18 parks. The overall aim is the transfer of life science research into commercial use and to
19
20 establish a cluster mainly in the London region. This should be achieved through financial
21
22 support and training (MAS, 2007).
23
24

25
26 Finally, the support of the emerging life science cluster in the Vienna region is another
27
28 example for start-up support in biotechnology clusters in Europe. The measures
29
30 implemented aim at the use of research for industry applications by providing, for example,
31
32 business seminars for researchers and by supporting company foundations
33
34 (ENICHELMEIR and OBERHOLZNER, 2007). The Scottish policy focuses its start-up
35
36 support on more mature clusters. The ambition is to turn high-end research into
37
38 commercialisation. An example is the Micro & Opto Electronics cluster in Scotland, where
39
40 the focus is on both spin-out and start-up firms. Furthermore, intermediary technology
41
42 institutes aim at the commercialisation of research in order to support the development of
43
44 clusters by providing funding for market oriented R&D. In addition, they can improve local
45
46 conditions and thus influence the probability of the creation of new firms (MAS, 2007).
47
48
49
50

51
52 Another option is the financing of young and promising firms. However, there are different
53
54 ways how to organise financial start-up support as well as how this support could affect
55
56 start-up activities. The applied measures range from the initial to the mature phase as
57
58 young innovative companies are important in every developmental phase of a cluster
59
60 (WOLFE and GERTLER, 2006). In the London Biotechnology Cluster, the establishment

1
2 and support of a seed fund is used to prevent young firms from financing shortfalls,
3
4 especially in the embryonic cluster phase when venture capital firms do not exist, yet
5
6 (MAS, 2007). The Estonian government, for example, puts a stronger focus on supporting
7
8 SME by offering state guarantees for loans, leases and bank guarantees as well as
9
10 traditional venture capital funds for operating and fast growing small companies. This
11
12 approach is especially implemented in the emerging phase of clusters. In contrast, in
13
14 Sweden the establishment of venture capital and services, e.g. business angels, is used
15
16 as a measure to guarantee the number of firms in a mature cluster (DINNETZ, 2007).
17
18
19 To sum up, policy measures that aim at increasing the regional start-up activity are applied
20
21 to clusters in all stages of their life-cycle.
22
23
24
25
26
27
28

29 *Network organisation and cooperation support*

30
31
32 Quite often, network policy and cluster policy are treated synonymous; especially by policy
33
34 makers. Frequently, policy makers support regional network organisation or cooperation
35
36 and call these measures cluster policy. However, networks are only one part of the
37
38 complex structure and dynamics of clusters; focusing only on this part does not satisfy the
39
40 holistic cluster approach (KIESE, 2008). Hence, we argue that the support of network
41
42 organisations and cooperation is one way among many others to support clusters.
43
44
45

46
47 The support of network organisation and cooperation seems to be less important in later
48
49 stages of the cluster life-cycle. The focus on network organisation is more relevant in the
50
51 initial and expansion phase when it becomes important to establish well functioning
52
53 networks and cooperation between the different actors in the cluster. In these stages, the
54
55 actors are often technologically scattered; furthermore, the uncertainty about the cluster's
56
57 development is high. Thus, networks represent a possibility to minimize risks. Even in the
58
59 growing phase networking plays an essential role to prevent isolation and help to generate
60

1
2 a positive environment. In this phase, cluster organisations and networks supporting the
3
4 local infrastructure help to address the needs of the cluster members (MENZEL and
5
6 FORNAHL, 2007). HUGGINS (2008) also highlights the significance of networks for the
7
8 development of clusters, which are in these early stages mainly informal with frequent
9
10 contacts and strong ties. When becoming a growing cluster, the mode of interaction
11
12 changes to more formalized networks and cooperation, which have established during the
13
14 initial phases. However, network support is also of some significance in later stages of the
15
16 cluster life-cycle when networks become mature, inducing an endangerment of over-
17
18 embeddedness and lock-in.
19
20
21

22
23 It can be distinguished between inter-firm cooperation, cooperation between firms and
24
25 public research institutes, and overall networking in a cluster. The main concern is to
26
27 support already existing regional activities and, thus, to stimulate emerging networks and
28
29 cooperation. The Austrian government supports networks and cooperation in various ways
30
31 (ENICHELMAIR and OBERHOLZNER, 2007). Mainly in the embryonic phase, the
32
33 government tries to enhance networking in the life-science cluster in the Vienna region by
34
35 creating contacts between the different members like co-operation partners and financiers.
36
37 In Lower Austria, the integration of large firms and SME in co-operation networks should
38
39 help to increase the innovativeness of the involved firms. In the first case, the focus is on
40
41 networks including all members of the cluster whereas in the second case only inter-firm
42
43 networks are promoted. But also cooperation between research and industry are
44
45 supported in order to strengthen high-end research in a certain field by providing industry
46
47 coordinators.
48
49
50
51
52
53

54
55 Denmark's cluster policy focuses on emerging networks (SCHOU, 2007). A joint secretariat
56
57 should help to coordinate collective activities, such as knowledge exchange, and function
58
59 as a connection between firms, institutes and education set-ups. Thus, the focus is on
60
general networks for all cluster members. Other possible measures supporting clusters in

1
2 the early stages of the life-cycle are conferences, meetings and other regional learning
3
4 processes. Facilitators should help to connect the different cluster members and create
5
6 networks between them. No evaluation has been carried out yet, but different positive
7
8 developments concerning the cooperation between firms have been observed.
9

10
11 As networks and cooperation grow older, there are some policies aiming at the renewal of
12
13 networks and cooperation in later stages of the cluster life-cycle. Over-embeddedness and
14
15 a possible lock-in in a mature stage should be prevented by developing and mobilizing
16
17 human capital and new linkages between actors. New modes of interaction can help to
18
19 renew deadlocked networks and cooperation (HUGGINS, 2008; RAINES, 2000). The
20
21 Spanish cluster policy focuses on the renewal of networks, communication and collective
22
23 identity in order to support mature clusters. For this purpose, the development of weak or
24
25 even non-existing ties in the value chain brings new options for collaborations and network
26
27 partner into the cluster. This is implemented by financial support for common projects of
28
29 the cluster members as well as the creation of physical space for cooperation (MÜLLER,
30
31 2007).
32
33
34
35
36
37

38 A widespread problem of cluster policies aiming at the development of networks is the
39
40 strong inward-looking focus. This does not imply that the internal cohesiveness of a cluster
41
42 is of no importance; however, outward-looking networks and communication are crucial to
43
44 bring new ideas into the cluster. Nevertheless, these outward-oriented networks are often
45
46 neglected (BATHELT et al., 2004).
47
48
49

50 To sum up, the support of regional networking and cooperation is mainly done in the earlier
51
52 stage of the cluster life-cycle. However, there are also policy measures focussing on
53
54 networks and cooperation which are applied in mature stages aiming at the cluster's
55
56 renewal.
57
58
59
60

Infrastructure and local conditions

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Infrastructure and local conditions are in general seen as important factors for the economic development of a region. As the cluster grows, the qualitative and quantitative needs in a region change and require adjustment and improvement. Often, local conditions fulfil the needs for a cluster's emergence but not for its growth. Therefore the improvement of these conditions is important in emerging and growth phases (MENZEL and FORNAHL, 2007). However, if a cluster becomes mature and successful, large infrastructure investments become more likely. If a cluster is still in a developing phase, the set-up of airports, highways or new universities and research institutes is attended by uncertainty. It needs a strong lobby which is more likely to be found in a mature cluster with strong ties between the different actors (BRENNER, 2008). Nevertheless, no empirical examples have been found.

Summary

Table 1 lists all measures including the different stages the measure is more likely to succeed. Obviously, for some measures it is difficult to distinguish between the different phases.

Table 1: Policy measures and the different stages the measure is more likely to succeed

III. Model

As stated above, there is only little empirical evidence for the effects of different policy measures supporting clusters so far. If evaluations of conducted programs do exist, they neither compare different approaches nor do they examine the effects with respect to the cluster's current stage of development. We expect more empirical evidence to be collected

1
2 in the future. However, at the moment, a theoretical approach seems to be more helpful.
3
4

5 The idea behind our theoretical approach is to develop a mathematical model of industry-
6 specific regional development and then to use this model to deduce knowledge about the
7 impact of different policy measures conducted at different points in time. First, we give a
8 verbal description and discussion of the model (Section III.1). In Section III.2 the
9 mathematical formulas describing our model are given. The estimation of the model
10 parameters is described and discussed in Section III.3.
11
12
13
14
15
16
17
18
19
20
21

22 Our approach proceeds as follows. We build a model that describes the regional industry-
23 specific developments in general (Sections III.1, III.2 and III.3). Then, we determine how
24 this model differs with respect to the various stages of the cluster life-cycle (Section III.4).
25 Finally, we define a number of potential policy measures, implement their direct impact
26 within the model, and study their effect on regional development (Section IV).
27
28
29
30
31
32
33
34
35
36

37 III.1 Basic considerations and model structure

38 In a first step, we set up a model that describes regional industry-specific development. Of
39 course, such a model can be set up in an arbitrarily complex way including a large number
40 of variables. We pursue two aims that influence the kind of model we develop. First, the
41 model should be as simple as possible in order to conduct a comprehensive analysis of
42 the effects of the different policy measures. Second, the model's parameters and
43 mathematical formulas are empirically estimated as far as possible to ensure the model's
44 reliability.
45
46
47
48
49
50
51
52
53
54
55
56

57 This has two implications for the variables used in our model. First, the number of
58 variables should be kept as small as possible. Second, variables should only be used if the
59 variable itself, their dynamics, and their interaction with other variables can be studied
60

1
2 empirically.

3
4
5 Two kinds of variables have to be distinguished. On the one hand, there are endogenous
6
7 variables, i.e. variables whose dynamic can be described by all other variables. On the
8
9 other hand, there are exogenous variables. Their impact on the endogenous variables is
10
11 implemented in the model, but no causal dependence in the opposite direction is
12
13 considered. Of course, in reality all variables are endogenous. In theoretical models, the
14
15 number of endogenous variables determines whether a model is analytically treatable
16
17 while the number of exogenous variable can be as large as the modeller wishes. Thus, the
18
19 endogenous variables have to be chosen with care.
20
21
22
23

24 We want to model the development of clusters. The variables that are used commonly in
25
26 the literature to identify clusters empirically are the location quotient and the number of
27
28 employees (SFORZI, 1990, STERNBERG and LITZENBERGER, 2004, BRENNER,
29
30 2006). The location quotient is an index based on the employment numbers. Hence, the
31
32 number of employees seems to be an adequate variable to measure the development of
33
34 clusters and the success of policy measures, although policy makers might aim at more
35
36 than employment growth. Employment is the central endogenous variable in our model.
37
38
39

40
41 Other variables that play a prominent role in the cluster literature are the number of firms,
42
43 start-ups, innovations, networks, human capital, spillovers, venture capital and many more
44
45 (see BRENNER and MÜHLIG, 2007 for a comprehensive list of factors and mechanisms).
46
47

48 In our model, we include the number of start-ups, the number of innovations and the
49
50 strength of networking as further endogenous variables. This is a subjective choice that is
51
52 partly driven by the availability of data and partly by our evaluation of the variables'
53
54 importance. Some aspects, such as human capital and spillovers, are somehow implicitly
55
56 integrated in the model. As mentioned above, we have to neglect some variables. Our
57
58 choice of variables can – to a certain degree - be justified by the findings of BRENNER
59
60 (2001). According to Brenner, for the fundamental characteristics of cluster models it does

1
2 not matter whether only one or more self-augmenting processes are included.
3
4

5 Hence, our model consists of one central endogenous variable, employment, three further
6 endogenous variables, start-ups, innovations and networks, and a number of exogenous
7 variables, education, public research, market conditions, population, governmental start-up
8 support, innovation support, network support and local infrastructure. The model's
9 structure is depicted in Figure 1.
10
11
12
13
14
15
16
17
18
19

20 Figure 1: Structure of the mathematical model
21
22
23
24
25

26 As stated above, the model does not include all interactions that are relevant for the
27 development of clusters. First, we have restricted the model to a small number of
28 endogenous variables. Second, we only consider further variables that correspond with
29 our basic categories of policy measures that we defined above. However, we believe that
30 the most important aspects are included. The strength of the model is that it can be
31 empirically validated, at least in its main elements.
32
33
34
35
36
37
38
39
40
41
42

43 III.2 Mathematical formulas of the model 44 45

46 Above, all variables of the model have been defined and discussed. In the mathematical
47 formulation we use the following abbreviations:
48
49

- 50
- 51 ● e_t : employment
- 52
- 53 ● i_t : number of innovations
- 54
- 55 ● s_t : number of start-ups
- 56
- 57 ● x_t : intensity of network activities
- 58
- 59 ● r_t : public research expenditure
- 60

- 1
- 2 • l_t : amount of qualified labour
- 3
- 4
- 5 • p_t : population (number of inhabitants)
- 6
- 7
- 8 • m_t : market conditions
- 9
- 10
- 11 • $f_{f,t}$: local infrastructure
- 12
- 13
- 14 • $f_{s,t}$: start-up support
- 15
- 16
- 17 • $f_{x,t}$: network support
- 18
- 19 • $f_{i,t}$: innovation support
- 20
- 21

22 In order to keep the analysis as simple as possible and make the mathematical model
 23 treatable, we do not consider interdependencies between regions. Hence, the model
 24 reflects the development within one cluster. The cluster's economic environment is
 25 considered only within the variable m_t , reflecting the global market situation. This implies
 26 that all other variables refer to the region and the industries involved in the cluster under
 27 consideration.

28 As stated above, the development in time is explicitly modelled only for the endogenous
 29 variable. In the following, we set up the dynamic equations for these four variables.

44 *Employment*

45 Empirical examinations prove that the dynamics of regional employment show the same
 46 characteristics as the growth of firms (SCHLUMP and BRENNER, 2010). They are best
 47 modelled on logarithm scale and by defining an attraction value for the employment
 48 number, \hat{e}_t , towards which the change of employment converges:

$$57 \ln(e_{t+1}) = \ln(e_t) + \ln\left(\frac{\hat{e}_t}{e_t}\right) + u_e. \quad (1)$$

58 u is the usual error term that reflects the randomness of the dynamics. SCHLUMP and
 60

BRENNER (2010) find that the attraction value, \hat{e}_t , depends on various variables that characterise the regional situation. For some of these variables the dependence is additive, while for some variables it is multiplicative. For each variable influencing the change of employment we have examined empirically whether the variable should enter the equation above additively or multiplicatively (for detailed explanations of the approach see SCHLUMP and BRENNER, 2010). As a result, we model \hat{e}_t by

$$\hat{e}_t = (\gamma_{e,e} \cdot e_t + \gamma_{e,s} \cdot s_t + \gamma_{e,l} \cdot l_t + \gamma_{e,r} \cdot r_t + \gamma_{e,f} \cdot f_{f,t}) \cdot LQ_t^{\gamma_{e,q}} \cdot m_t^{\gamma_{e,m}} \cdot i_t^{\gamma_{e,i}} \cdot x_t^{\gamma_{e,x}} \cdot \left(\frac{p_t - e_t}{p_t} \right)^{\gamma_{e,p}} \quad (2)$$

where LQ stands for the location quotient which is defined as usual by

$$LQ_t = \frac{e_t \cdot E_{glob,t}}{e_{glob,t} \cdot E_t},$$

“glob” signifies that a variable relates to the whole world, E is the employment in all industries and the γ 's stand for various parameters that determine the strength of the relationship between the various variables and employment.

Start-ups

In order to model the number of start-ups we use the approach of BRENNER and FORNAHL (2008) in which the number of start-ups is modelled as a binomial distribution with the number $\hat{n}_{s,t}$ of potential founders given by

$$\hat{n}_{s,t} = \varphi_{s,p} \cdot p_t + \varphi_{s,e} \cdot e_t + \varphi_{s,l} \cdot l_t + \varphi_{s,r} \cdot r_t \quad (3)$$

and the probability $P_{s,t}$ that each of the potential founders really starts a firm given by

$$P_{s,t} = \frac{1}{1 + \exp[\varphi_{s,0} - \varphi_{s,f} \cdot f_{s,t}]} \quad (4)$$

All φ are parameters that we estimated empirically (see Section III.3). The way in which

the variables are included in Equations (3) and (4) is extensively discussed and estimated empirically by BRENNER and FORNAHL (2008).

Innovations

To model innovations we use the same approach as for the number of start-ups and distinguish between potential innovators and their probability to innovate (for a detailed discussion of this distinction see BRENNER and BRÖKEL, 2009). We denote the number of potential innovators by $\hat{n}_{i,t}$. We tested empirically a number of different variables, e.g. research institutes and universities. We found that only two variables significantly influence the number of potential founders: the *population* p_t and the *employment* e_t . The employment has a much stronger impact on the regional start-up activity. Neglecting the population's impact, the later analysis can be simplified tremendously, so that we write:

$$\hat{n}_{i,t} = v_{i,e} \cdot e_t \quad (5)$$

All other variables influence the probability $P_{i,t}$ that these potential innovators conduct an innovation in a given year. This probability is found to be given by

$$P_{i,t} = \frac{1}{1 + \exp[v_{i,0} - (v_{i,r} \cdot r_t + v_{i,f} \cdot f_{i,t})]} \quad (6)$$

All v in Equations (5) and (6) are parameters.

Networking

In contrast to employment, start-ups and innovations, there are no empirical studies available yet that illustrate the interrelation between the intensity of local networking and other local variables. We assume a similar structure as for start-ups and innovations.

Again, the more employees are present in a region, the more network activity might

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

develop. However, this increase in network activity might be non-linear. Since we are not able to check this assumption empirically, we choose a flexible formulation. In addition, the network intensity depends on the some local characteristics and the network support present. We define, without being able to test this empirically:

$$x_t = \frac{v_{x,e} \cdot e_t^{\gamma_{x,e}}}{1 + \exp[v_{x,0} - v_{x,f} \cdot f_{x,t}]} + u_x \quad (7)$$

Again, all v are parameters and u is the usual error term.

Limitations of the model

There are two main limitations of the model. First, we only include a number of variables for most of which empirical data is available so that we can estimate the relationships reflected in the model. A number of potentially influential variables are ignored. The variables that are most frequently assumed to be important in the literature are included. However, industries differ and the various variables are of different importance in the industries. Therefore, there might be industries whose main mechanisms cannot be represented by our model. In theoretical literature it is usually argued that the exact mechanisms do not matter. Often local externalities are included in a quite sketchy manner. BRENNER (2001) provides evidence that a detailed modelling of all relevant processes might, indeed, not be of crucial importance. From this, we might conclude that the dynamics of cluster formation are well reflected by our model, although not all details are included in the model.

The same does not hold for the impact of policy measure. The model only allows us to examine those policy measures for which the way they influence the regional development is explicitly included in the model. Policy measures can be designed in many different ways. Thus, they have distinct impact on the different aspects of the complex development

1
2 of clusters. Not all of them are reflected in the model. Above, we categorised the potential
3
4 policy measures. Each category does summarise a number of different activities and
5
6 mechanisms. In most cases, only one mechanism is implemented in the model as
7
8 representative of the category. This implies that not all measures are represented
9
10 adequately. Therefore, we are only able to draw reliable conclusions for those measures
11
12 implemented in our model.
13
14

15
16 Second, we only consider one industry and one region at a time. This simplifies the model
17
18 tremendously in order to make a mathematical analysis possible. However, this implies
19
20 that we do not model interrelations between industries and between regions. Part of the
21
22 interregional interrelations is reflected in the market situation, m_t . Furthermore, a number
23
24 of variables that represent the situation in the region are included in the model. If
25
26 neighbouring regions have an impact on the regional developments, we might represent
27
28 these impacts by those variables. Hence, from a mathematical perspective, it makes no
29
30 difference whether we include other regions and industries or not as long as the
31
32 interrelations with other regions and industries do not lead to endogenous dynamics.
33
34

35
36 Furthermore, in a theoretical approach we do not have to define industries and regions
37
38 beforehand. We are able to declare that all activities that belong to the cluster examined,
39
40 irrespective of industrial classifications and regional borders, are included in the analysis.
41
42 This is, of course, not possible in the calibration of the model using the empirical data
43
44 below.
45
46
47
48
49
50

51 52 53 III.3 Model validation and calibration 54

55
56 Above, we have argued that the results of our modelling approach are only reliable if the
57
58 model is validated and calibrated using empirical data. Three topics have to be addressed.
59
60

First, we have to find the adequate variables that should be included in the model. This

1
2 topic is discussed above.
3

4
5 Second, the model has to represent the interrelations between these variables adequately.
6

7 This means the functional form of the interrelations has to match reality. As stated in
8

9
10 Section III.2, we used findings from previous studies and conducted additional empirical
11

12 tests in order to find out whether the variables influence each other in additive or
13

14 multiplicative ways. For all variables that we have empirical proxies for the above
15

16 equations represent the form that fits reality best. An exception is the network variable, x_t .
17

18 For this variable, we do not have adequate data so that the equation for this variable is
19

20 much less reliable.
21
22

23
24 Third, the model has to be calibrated. This means that the parameters of the model have
25

26 to represent reality adequately. For this calibration we use data for the German labour
27

28 market regions for the time period from 1999 to 2007. For most of the variables included in
29

30 the model we have exact data or, at least, some proxies. The data sources are the
31

32 German Statistical Office, the German Patent Office, and the German Institute for Labour.
33

34 We have data on the employment, e_t , the number of start-ups, s_t , and the number of
35

36 inhabitants, p_i . For the number of innovations, i_t , we use the number of patents as a proxy.
37

38 Qualified labour, l_t , is approximated by the number of university graduates; public research
39

40 expenditures, r_t , are approximated by the number of employees in public research
41

42 institutes.
43
44

45
46 The idea behind the model's calibration is not to obtain exact values for the parameters,
47

48 but to ensure the size of the parameters is approximately correct. The aim is to obtain a
49

50 reliable model and not to estimate effects empirically (for such estimations see BRENNER
51

52 and FORNAHL, 2008; SCHLUMP and BRENNER, 2010). Therefore, the use of proxies
53

54 seems to be adequate.
55
56

57
58 Anyhow, the parameters differ between industries. One correct set of parameters does not
59

60 exist. Hence, we conduct the calibration of the model for a number of industries

1
2 separately: textiles, chemicals, metal, machinery, automotive, electrical and instruments.

3
4 We decided to use these industries since there does exist a good concordance between
5
6 the industries' classification and the respective patent classes. This provides us with
7
8 knowledge about the parameter values as well as some insights about whether they
9
10 depend on the stage of the industrial life-cycle. The median estimates of the parameters
11
12 are presented in Table A.1 in the appendix. If we can observe a clear dependence of a
13
14 parameter on the age of the industry , we state this also in Table A.1.
15
16
17

18
19 The parameter values are, of course, crucial for the results we obtain below. We use the
20
21 median values estimated for a number of industries. This implies that not all industries are
22
23 represented adequately by the resulting model. Therefore, we have to discuss how the
24
25 results change if the parameters are different. Furthermore, some industries might possess
26
27 specific features and, thus, exhibit extreme values for some parameters. Hence, we can
28
29 never be sure that our results hold for all industries. Since the industrial and regional
30
31 classifications used in the empirical analysis might not be adequate, the aim of the
32
33 analysis can only be to find some tendencies describing the effectiveness of the various
34
35 policy measures that hold for the average industry. For this reason, we do not use the
36
37 empirical obtained parameters as exact values but to give us an impression about the
38
39 approximate size of the parameters. However, it is important to know, at least, something
40
41 about the values of the parameters; otherwise we might deduce arbitrary results from the
42
43 model. Robustness checks show some evidence that the results are likely to hold for most
44
45 industries.
46
47
48
49
50
51
52
53
54

55 III.4 Modelling the stages of the cluster life-cycle

56
57
58 The model above describes the regional employment dynamics in relation to a number of
59
60 other variables. Thus, it describes the emergence and development of clusters if we define
a cluster basically as an agglomeration of specific economic activity in a region. Many of

1
2 the mechanisms assumed to be important for the development of clusters are included in
3
4 the model above.
5
6

7 The importance of these mechanisms changes during the different stages of the cluster
8
9 life-cycle. The aim of this paper is to study how these changes influence the effectiveness
10
11 of different policy measures. In the model, a change in the mechanisms' importance is
12
13 reflected by a change of the parameters' values. Hence, to understand the differences
14
15 between the distinct stages of the cluster life-cycle by means of the model we have to
16
17 know how the parameters differ between these stages.
18
19

20
21
22 There are two sources for obtaining information on these differences: the theoretical
23
24 discussion of the cluster life-cycle as presented in Section II.1 and empirical estimations of
25
26 the parameters for different industries. Table A.1 lists the parameters and their changes
27
28 during the cluster life-cycle that are predicted on the base of different theories and
29
30 empirical estimations.
31
32

33
34 Of course, clusters do not jump from one stage to another. As discussed above, there are
35
36 transition phases. Similarly, the parameter values should not be expected to jump from
37
38 one value to another. While the cluster transits from one stage to another, we rather expect
39
40 them to continually decrease or increase. However, we are mainly interested in the
41
42 effectiveness of policy measures within the different stages. Thus, the analysis of the
43
44 model focuses on the three main stages of the cluster life-cycle.
45
46
47
48
49
50

51 IV. Analysis, results and discussion

52 IV.1 Analysis of the model

53
54
55 In order to analyse the model, we rewrite Equations (3), (4), (5) and (6) such, that they
56
57
58 have a similar structure as Equations (2) and (7):
59
60

$$s_t = \frac{\varphi_{s,p} \cdot p_t + \varphi_{s,e} \cdot e_t + \varphi_{s,l} \cdot l_t + \varphi_{s,r} \cdot r_t}{1 + \exp[\varphi_{s,0} - \varphi_{s,f} \cdot f_{s,t}]} + u_s \quad (8)$$

and

$$i_t = \frac{v_{i,e} \cdot e_t}{1 + \exp[v_{i,0} - (v_{i,r} \cdot r_t + v_{i,f} \cdot f_{i,t})]} + u_i \quad (9)$$

In these two equations, the error terms are neither symmetrically distributed nor they are independent from the values of the parameters. However, this transformation allows to insert Equations (7), (8) and (9) into Equation (2).

In the resulting equation, the error terms are quite complex and a mathematical treatment of the model including these error terms is not possible. The aim of our mathematical analysis is to examine the influence of the parameters and exogenous variables on the dynamics. We are not able to fit the parameters and model real developments exactly. However, we are interested in the direction of the parameters' impacts. For this aim, an analysis of the model excluding the error terms is sufficient.

Ignoring the error terms, we obtain the still quite complex Equation (A.1), which is given in the appendix. Equation (A.1) contains terms that depend on employment e_t and terms that depend only on the exogenous variables and the parameters. For the analysis of the dynamics of e_t the terms depending on variable e_t are of special importance. They determine the structure of the dynamics. Therefore we separate these two kinds of terms and use abbreviations in Equations (A.2), (A.3), (A.4) and (A.5) for the terms that do not include e_t . We obtain

$$\log(e_{t+1}) - \log(e_t) = \log \left[c_t \cdot (a_t \cdot e_t^\alpha + b_t \cdot e_t^{\alpha-1}) \cdot \left(\frac{p_t - e_t}{p_t} \right)^{\gamma_{e,p}} \right] \quad (10)$$

Let us first examine the term within the logarithmic function on the right-hand side of Equation (10):

$$L(e_t) = c_t \cdot \left(a_t \cdot e_t^\alpha + b_t \cdot e_t^{\alpha-1} \right) \cdot \left(\frac{p_t - e_t}{p_t} \right)^{\gamma_{e,p}} \quad (11)$$

This term shows a clear dependence on the number of employment e_t . For $L(e_t)$, we obtain a functional form that looks as depicted in Figure 1.

For further mathematical treatment, we use the following assumption:

Assumption 1: Cluster forces play a role for the cluster's development. Mathematically, this is given if the last term in Equation (10) plays no role for small values of e_t and the term $b_t \cdot e_t^{\alpha-1}$ plays no role for large values of e_t .

Figure 2: Function $L(e_t)$ for the median parameter values and a region with 800,000 inhabitants.

Assumption 1 allows us to distinguish between the case of low and medium employment, for which negative local externalities play no role, and the case of high employment, for which the dynamics are determined by cluster forces and negative externalities only. In the appendix, we prove the following results:

Proposition 1: If Assumption 1 is satisfied, the local system shows one of the following three dynamics:

- A) *The system has one stable state that is characterised by a low number of employment. The system converges to this sole stable state. We find such a dynamic if*

$$c_t \cdot a_t \cdot p_t^\alpha \cdot \frac{\gamma_{e,p}^\alpha + \alpha^{\gamma_{e,p}}}{(\gamma_{e,p} + \alpha)^\alpha} < 1 \quad (8A2)$$

is satisfied.

B) The system has two stable states of which one is characterised by a low number of employment and the other by a high number of employment. The system converges to one of these two stable states depending on the state the system is currently in.

We find such a dynamic if $\alpha < 1$,

$$c_t \cdot b_t^\alpha \cdot a_t^{1-\alpha} \cdot \left[\left(\frac{1-\alpha}{\alpha} \right)^\alpha + \left(\frac{\alpha}{1-\alpha} \right)^{1-\alpha} \right] < 1 \quad \text{and}$$

$$c_t \cdot a_t \cdot p_t^\alpha \cdot \frac{\gamma_{e,p}^\alpha + \alpha^{\gamma_{e,p}}}{(\gamma_{e,p} + \alpha)^\alpha} > 1 \quad (8B2)$$

or if $\alpha > 1$ and Condition (8B2) is satisfied.

C) The system has one stable state that is characterised by a high number of employment. The system converges to this sole stable state. We find such a dynamics if $\alpha < 1$ and

$$c_t \cdot b_t^\alpha \cdot a_t^{1-\alpha} \cdot \left[\left(\frac{1-\alpha}{\alpha} \right)^\alpha + \left(\frac{\alpha}{1-\alpha} \right)^{1-\alpha} \right] > 1$$

Proposition 1 means that, depending on the model's parameters, we find one of three possible dynamics in a region. The first possible dynamic (A) predicts that no cluster will emerge or an existing cluster will disappear. The second possible dynamic (B) predicts that if the critical mass is exceeded, a cluster will emerge or stabilise, while no cluster will appear as long as the regional economic activity is below the critical mass. The third possible dynamic (C) predicts that a cluster will emerge or stabilise irrespective of the current regional activity. The parameters of the model determine what kind of dynamics will occur. Moreover, as argued above, the parameters of the model change during the cluster life-cycle and can be influenced by various policy measures. These are the impacts we

1
2 want to analyse.
3

4
5 Before examining the impact of policy measures and the different stages of the cluster life-
6
7 cycle, let us check the relevance of Proposition 1 for the median case. If the market
8
9 situation is average, i.e. demand and supply are in an equilibrium ($m_t = 1$), a region with no
10
11 university and no relevant public research institute falls into category B if it has many
12
13 inhabitants (more than approximately 550000); if a region has not that many inhabitants, it
14
15 falls into category A. The former case is depicted in Figure 1 with the two stable states
16
17 marked by a star. Hence, for an average industry, both situations, clustering and no
18
19 clustering, are stable in large regions.
20
21
22

23
24 Category C is found if the local positive externalities (given by α and a_t) are of high
25
26 intensity or the market conditions are favourable (high value of m_t). In addition, positive
27
28 local circumstances that influence the value of b_t make category C more likely but have a
29
30 much smaller impact than the other variables depicted above. However, category C is not
31
32 a standard case, which implies that clusters do not emerge everywhere at all times.
33
34
35
36
37
38

39 IV.2 Theoretical impact of policy measures 40 41

42 The model above allows us to check the impact of various policy measures on the
43
44 dynamics of the local system during different phases of the cluster life-cycle. We proceed
45
46 in three steps. First, we use the mathematical findings of Section IV.1 in order to identify
47
48 the kind of dynamics likely to occur in the three stages of the cluster life-cycle.
49
50

51 Furthermore, we discuss to what extent these dynamics are influenced by the values of
52
53 the terms a_t , b_t and c_t in Equation (10). Second, we list the relevance of each policy
54
55 measure means in terms of the mathematical model and how these policy measures
56
57 influence the terms a_t , b_t and c_t . Third, we combine the results from the first two steps and
58
59 analyse the policy measures' impact in the three phases of the cluster life-cycle (Section
60

1
2 IV.3).
3
4
5
6
7

8 *Dynamics in the three stages of the cluster life-cycle*
9

10 Above, we found that three kinds of dynamics are possible: Dynamics A, B and C. We also
11 found that for the median parameters we rather have to expect Dynamics A or B. However,
12 there are differences between industries and, as discussed above, the parameters change
13 during the cluster life-cycle. These changes are listed in Table A.1 in the appendix. In the
14 following we use this knowledge in order to find out whether certain kinds of dynamics are
15 more likely to occur in certain stages of the cluster life-cycle.
16
17
18
19
20
21
22
23

24 Above we argued that we cannot be sure about the values of the parameters. They differ
25 between industries and empirical estimates only give some crude knowledge about the
26 parameters' size. We will consider this in the analysis below. This means, that we only use
27 the estimated parameters to get a feeling for the most likely situation. However, we will
28 also discuss the implications for parameters deviating from these values.
29
30
31
32
33
34
35

36 Before we examine the different stages, we discuss what conclusions can be drawn for the
37 expected dynamics from the values of the terms α , a_t , b_t and c_t . Proposition 1 tells us that
38
39
40
41

- 42
43
44
45
46
47
48
49
50
51
52
- Dynamic A is expected if a_t and c_t are small.
 - Dynamic B is expected either if a_t and c_t are large and α is bigger than 1 or if b_t is small.
 - Dynamic C is expected if a_t , b_t and c_t are large and α is smaller than 1.

53 Now, we discuss what the parameter values listed in Table A.1 imply for the terms α , a_t , b_t
54 and c_t for the different stages of the cluster life-cycle. We discuss each stage separately (a
55 summary is given in Table A.2 in the appendix):
56
57
58
59
60

- Initial phase: The term α depends on parameters that, in the initial phase, are either

1
2 small or medium. Hence, α is small and definitely below 1 in this phase. The
3
4 parameters that determine a_t are either small or very large. We expect a medium
5
6 value of a_t , although this is not as clear. Many parameters are involved in the term
7
8 b_t . In the initial phase, all of them are large or very large so that we expect a very
9
10 large value of b_t . The parameters that determine term c_t are medium or small so that
11
12 we expect a small value for c_t . These values imply that Dynamic B are not possible
13
14 or, at least, very unlikely. Most likely we will see Dynamic C and there is some
15
16 chance to find Dynamic A.
17
18
19

- 20
21 • Expansion phase: In this phase, all parameters that determine the value of α are
22
23 either large or very large. Hence, α is very large in this phase. However, α is, on
24
25 average, 0.5 so that it is likely that α is above 1 in this phase. The term a_t can be
26
27 expected to be very large because all crucial parameters are large or very large.
28
29 Most of the values involved in term b_t are either large or very large in the expansion
30
31 phase. However, one parameter is medium. Thus, we expect the term b_t to be large
32
33 but this is less clear. Almost all parameters that determine term c_t are very large so
34
35 c_t should also be very large. These expectations for the terms α , a_t , b_t and c_t make
36
37 Dynamic A impossible or, at least, very unlikely. It is unclear whether Dynamics B or
38
39 C should be observed.
40
41
42
43
44
- 45 • Mature phase: The parameters that determine the value of α range between
46
47 medium and very large. Hence, α can be expected to be large but it has to be
48
49 doubted whether it is greater than 1. The term a_t has a rather small value since the
50
51 parameters involved are between small and medium in this phase. Term b_t is
52
53 expected to take a small value because all parameters involved are either small or
54
55 medium in the mature phase. In this phase, the parameters involved in term c_t vary
56
57 in their size. Most are medium but some are very large. Hence, the value of c_t is
58
59 less clear with an expectation between medium and large. It is less clear what kind
60

1 of dynamics should be expected here. The value of a_t implies rather Dynamic A.
2
3
4 However, the value of c_t might lead to Dynamics B or C, while a small value of b_t
5
6 makes Dynamic B more likely.
7
8

9 The arguments above are summarised in Table 2.
10
11
12
13
14

15 Table 2 Model implications for the dynamics in the three stages of the cluster life-cycle.
16
17
18
19
20
21
22
23

24 *Mathematical meaning and impact of the various policy measures*

25

26 It is important to list the implementation of the various policy measures in the model in
27 detail. As stated above, each of our policy measure categories contain many different
28 approaches that are likely to impact different variables and processes. In the mathematical
29 model, we implemented each category in exactly one way. Hence, from the analysis
30 below, we only obtain reliable information about the impact of those policy measures that
31 work exactly the way they are implemented in the model.
32
33
34
35
36
37
38
39
40

41 Hence, in the following, we discuss three topics for each policy measure category: 1)
42 which variable is used to represent the measure in the model, 2) which real effects and
43 processes are reflected, and 3) how does this impact on Equation (10).
44
45
46
47
48

- 49 • Education: Education is reflected in the model by the amount of highly educated
50 people, l_t , (people with university degree). In the model, this is assumed to have an
51 impact on the number of start-ups and the growth of firms. However, in the model,
52 education is implemented as an exogenous variable which implies that learning on
53 the job is not represented. Improving or increasing education implies: $l_t \uparrow \rightarrow b_t \uparrow$,
54 especially if $\gamma_{e,h}$, $\gamma_{e,s}$ and $\gamma_{s,l}$ are large.
55
56
57
58
59
60

- 1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
- Public research: The amount of relevant public research in the region is directly included in the model by the variable r_t . It is assumed that this amount has an impact on the number of start-ups, innovations and the growth of firms. Increasing public research implies: $r_t \uparrow \rightarrow b_t \uparrow$, especially if $\gamma_{e,r}$, $\gamma_{e,s}$ and $\gamma_{s,r}$ are large and $c_t \uparrow$, especially if $\gamma_{e,i}$, $v_{i,e}$ and $v_{i,r}$ are large.
 - Supporting R&D and innovation culture: The model contains a variable, $f_{i,t}$ which reflects any support from the outside that increases the innovativeness of firms. Other effects are not assigned to this variable. Hence, all measures that only increase innovativeness are well represented by this variable. Increasing innovativeness implies: $f_{i,t} \uparrow \rightarrow c_t \uparrow$, especially if $\gamma_{e,i}$, $v_{i,e}$ and $v_{i,f}$ are large.
 - Support of start-ups: The model contains a variable, $f_{s,t}$ which reflects any support from the outside that increases the regional start-up rate. Other effects are not assigned to this variable. Hence, all measures that support start-up activities and, thus, make them more likely are well represented by this variable. Increasing start-up activity implies: $f_{s,t} \uparrow \rightarrow a_t \uparrow$, especially if $\gamma_{e,s}$, $\varphi_{s,e}$ and $\varphi_{s,f}$ are large and $b_t \uparrow$, especially if $\varphi_{s,f}$ is large.
 - Network organisation and cooperation support: The model contains a variable, $f_{x,t}$ which reflects any support from the outside that increases the regional network activities. Other effects are not assigned to this variable. Furthermore, the model includes only effects of networks on the growth of firms. Hence, all measures that support network activities and, thus, help firms to grow are well represented by this variable. If network support increases the start-up activity or innovativeness, such an effect is represented in the by the two variables, $f_{i,t}$ and $f_{s,t}$. Increasing network activity implies: $f_{x,t} \uparrow \rightarrow c_t \uparrow$, especially if $\gamma_{e,x}$, $v_{x,e}$ and $v_{x,f}$ are large.
 - Infrastructure and local conditions: The model contains a variable, $f_{e,t}$ which reflects any support from the outside that supports the growth of firms. All direct help to

1
2 firms can be subsumed under this label. Again, only this direct effect is reflected in
3
4 the model. If a policy measure has additional effects, other variable changes have
5
6 to be considered simultaneously. Increasing support of firms implies: $f_{e,t} \uparrow \rightarrow b_t \uparrow$,
7
8 especially if $\gamma_{e,f}$ is large.
9
10
11
12
13
14
15
16
17

18 IV.3 Impact of policy measures in the three stages

19
20 In the following, we discuss how the different policy measures outlined above influence the
21
22 cluster processes for each stage separately. Interpreting the model's result, it has to be
23
24 kept in mind that we are only able to make statements about policy measures that are
25
26 applied in the form described above.
27
28
29
30
31
32

33 *Initial phase*

34
35 According to the findings summarised in Table 1, the question in the initial phase is
36
37 whether a cluster emerges or not. In this phase, policy measures could be applied in order
38
39 to increase the probability of cluster emergence. This would imply that in the model the
40
41 likelihood of Dynamics C should increase and the likelihood of Dynamics A decreased.
42
43 According to Table 1, this is reached by measures that increase a_t and/or c_t . b_t does not
44
45 play a role.
46
47
48
49

50
51 According to the findings in Section IV.2, education, infrastructure and local conditions do
52
53 only influence the value of b_t but not the values of a_t and c_t . Hence, measures that aim at
54
55 education or infrastructure, and local conditions should not be expected to have an impact
56
57 in the initial phase of cluster development. They do not increase the likelihood of cluster
58
59 emergence.
60

In this context, we have to keep in mind that the above findings only hold for policy

1
2 measure that work as modelled here. This means that educational measures influencing
3
4 the growth of firms only have no impact in the initial phase. For example, educational
5
6 measures that increase regional start-up activity are not modelled explicitly in this context
7
8 and are subsumed in the support of start-up activity. Hence, for such educational
9
10 measures the statement above does not hold.
11
12

13
14 Public research is found to increase the term c_t so that the emergence of clusters becomes
15
16 more likely in regions in which the government conducts public research. According to the
17
18 findings above, this holds especially if $\gamma_{e,i}$, $v_{i,e}$ and $v_{i,r}$ are large. If innovations play an
19
20 important role in the considered industry, the first two parameters are large. The latter
21
22 parameter, $v_{i,r}$, is large if public research strongly contributes to the regional innovation
23
24 activity. Hence, in innovative industries, in which public research contributes significantly to
25
26 innovation activity, policy measures that support public research in the initial phase of the
27
28 cluster life-cycle increase the probability of cluster emergence.
29
30
31

32
33 Similar results are obtained for the support of private R&D activities or the support of a
34
35 regional innovative culture. Again, such support increases the likelihood of cluster
36
37 emergence. This is especially the case if innovations are important in the industry under
38
39 discussion (large $\gamma_{e,i}$ and $v_{i,e}$). Furthermore, the effectiveness of such policy measures
40
41 depend on $v_{i,f}$, a parameter describing the dependence of a firm's innovativeness on
42
43 outside factors. In other words, the model cannot state whether a certain kind of support of
44
45 private R&D is successful. However, if such a support is able to increase the
46
47 innovativeness of firms and innovations are important in the industry under discussion,
48
49 such support is an adequate measure in the initial phase of the cluster life-cycle.
50
51
52

53
54 The support of start-up activity increases the value of term a_t , especially if $\gamma_{e,s}$, $\varphi_{s,e}$ and $\varphi_{s,f}$
55
56 are large. Again, since we do not model start-up support in detail, the model has some
57
58 limitations. It might be financial support, organisational support, education of potential
59
60 entrepreneurs or any other kind of support. However, if there is support that significantly

1
2 increases the start-up activity (large $\varphi_{s,t}$), the emergence of a cluster becomes more likely
3
4 if start-ups play an important role in the industry (large $\gamma_{e,s}$ and $\varphi_{s,e}$).
5
6

7 Network organisation and cooperation support is an effective measure in the initial stage of
8
9 the cluster life-cycle if it succeeds to increase the network and cooperation activity (large
10
11 $v_{x,t}$) and if networking and cooperation is important in the industry under discussion (large
12
13 $\gamma_{e,x}$ and $v_{x,e}$). As stated above, we are not able to state how networking and cooperation
14
15 can be supported effectively. However, the model proves that they are adequate tools in
16
17 the initial stage.
18
19
20
21
22
23

24 *Expansion phase*

25
26
27 In the expansion phase, two different types of dynamics might occur: Dynamic B and
28
29 Dynamic C (see Section IV.2). Dynamic B stands for a stabilisation of the actual situation.
30
31 This means that if no cluster has emerged in the industry and region under discussion, so
32
33 far, no cluster will emerge in the expansion phase. Dynamic C, instead, causes the
34
35 emergence of a cluster if it is not already present. Hence, policy measures should attempt
36
37 to make Dynamic C more likely. This is achieved by small values of α and large values of
38
39 b_t . α depends on the characteristics of the respective industry as well as the stage of the
40
41 cluster life-cycle and cannot be influenced by policy measures. It becomes large during the
42
43 expansion phase so that the impact of policy measures is limited. Impacts are rather given
44
45 at the beginning of the expansion phase, when α is still smaller. The crucial term to be
46
47 influenced is b_t .
48
49
50
51
52

53
54 Above, we found that the support of networking and cooperation as well as the support of
55
56 private R&D has no impact on term b_t . This holds only for support that has an impact as
57
58 modelled here. However, for such kinds of policy measures we find no effects in the
59
60 expansion phase so that they are rather ineffective in this phase. Other policy measures

1
2 examined in this paper have the potential to influence the dynamics of cluster formation in
3
4 the expansion phase.
5

6
7 Education has an impact on b_t , especially if $\gamma_{e,l}$, $\gamma_{e,s}$ and $\gamma_{s,l}$ are large. This means that
8
9 policy measures, which lead to a higher education in the region und discussion, have an
10
11 influence on the emergence of clusters in the expansion phase of the cluster life-cycle.
12

13
14 The effectiveness of such measures depends on the industries need for skilled workers
15
16 (large $\gamma_{e,l}$) as well as on start-up activities and their need for educated potential founders
17
18 (large $\gamma_{e,s}$ and $\gamma_{s,l}$). Hence, if educated workers are important either for firms or the
19
20 founding of firms, the support of education is an adequate measure during, and especially
21
22 at the beginning of the expansion phase.
23
24

25
26 Similar findings are obtained for public research. Public research is an adequate measure
27
28 in the expansion phase, too, especially if public research is important for firms in the
29
30 industry under discussion (large $\gamma_{e,r}$) and/or if there is high start-up activity that can be
31
32 enhanced by public research (large $\gamma_{e,s}$ and $\gamma_{s,l}$).
33

34
35 Moreover, the direct support of start-up activities is effective in the expansion phase of the
36
37 cluster life-cycle. Again, the effectiveness depends on how much start-up activities can be
38
39 influenced by policy measures ($\varphi_{s,r}$). We are not able to deduce any knowledge about how
40
41 this can be reached from the model. We find that an increase of the regional start-up
42
43 activities during the expansion phase also increases the likelihood of the emergence of a
44
45 cluster.
46
47
48
49

50
51 Infrastructure and local conditions do also matter in the expansion phase of the cluster life-
52
53 cycle. The effectiveness of policy measures that improve these conditions depends on
54
55 their relevance for the industrial activity ($\gamma_{e,r}$). This means that policy measures have to be
56
57 adapted to the needs of the industry under consideration in order to be effective.
58
59
60

Mature phase

In the mature phase of the cluster life-cycle, the situation changes again. As stated above, in the mature phase, all three kinds of dynamics are possible. Dynamic B is most likely, which implies a stabilisation of the current state. This means that an existing cluster is stabilised, while if no cluster exists, no cluster will emerge. However, the (re-)emergence of a cluster (Dynamic C) is possible, if α is small and b_t and c_t are large. α decreases with time and is not influenced by any policy measures. Hence, the chances that a cluster emerges decrease with time. If c_t is small, an existing cluster can run the risk to disappear. Hence, in this phase, policy measures can have two aims. First, they might aim at making the (re-) emergence of a cluster more likely. Second, they might aim at avoiding the disappearance of an existing cluster. In both cases the value of c_t is important. Therefore, it is important to recognise that term c_t depends on the market condition (m_t). In the mature phase, strong competition and decreasing markets make the success of any policy measure less likely.

Furthermore, there are differences between the two policy aims. Avoiding the disappearance of an existing cluster requires keeping c_t sufficiently large, while making the (re-) emergence of a cluster more likely requires making b_t and c_t large.

Hence, in contrast to the expansion phase of the cluster life-cycle, supporting the (re-) emergence of a cluster in the mature phase requires not only increasing b_t , but also increasing c_t . This means that policy has either to choose a measure that increases both terms, b_t and c_t , at the same time or to choose measures that are discussed for the expansion phase and combine them with further measures.

The only measure able to influence b_t and c_t at the same time is public research. Hence, if innovations are important in the respective industry, if public research matters for innovative activities and if spin-offs from public research play a role, increasing public

1
2 research makes the (re-)emergence of a cluster more likely.
3

4
5 Besides, in the mature phase, the (re-)emergence of a cluster can be made more likely by
6
7 combining one of the measures from the expansion phase – education, support for start-
8
9 ups, and improvement of the infrastructure and local conditions – with support for private
10
11 R&D, networking or cooperation, which leads to an increase in c_t . This shows that it is
12
13 more difficult to trigger the emergence of clusters in the mature phase than in the
14
15 expansion phase. Furthermore, the potential of such an influence decreases with time.
16
17 The effectiveness of the different measures depends on the same parameters and thus
18
19 circumstances for each of the measures as discussed above.
20
21
22

23
24 To avoid the disappearance of an existing cluster in the mature phase of the cluster life-
25
26 cycle, the term c_t has to be large. The term c_t might become small in the mature phase due
27
28 to bad market conditions. Policy measures have to balance the negative effects. According
29
30 to the model, three measures have an impact on c_t and, thus, have the potential of a
31
32 positive impact that balances the negative market developments. These are public
33
34 research, support for private R&D and support of networking and cooperation.
35
36
37

38
39 Public research is especially effective if innovations are important (large $\gamma_{e,i}$ and $v_{i,e}$) and
40
41 public research contributes significantly to the innovation activities (large $v_{i,r}$). The former
42
43 also holds for the support of private R&D, while the effectiveness of outside support of the
44
45 firms' innovation activities is also important (large $v_{i,r}$). If networks and cooperation are
46
47 important in the industry (large $\gamma_{e,x}$ and $v_{x,e}$) and if policy can influence networks and
48
49 cooperation significantly (large $v_{x,f}$), the support of networking and cooperation is effective.
50
51
52

53 54 55 56 *Summary*

57
58
59 Summing up the results, we first have to state that these results only hold for policy
60
measures that function as considered in the model, e.g. in the model, networking is

1
2 assumed to have an effect on the growth of existing firms. If policy makers support
3
4 network activities that are especially helpful for founders and, therefore, increase the start-
5
6 up activity, this is not included in the model in the form of network support. It is rather
7
8 included in the start-up support, which represents all actions that are able to increase the
9
10 start-up activity.
11
12

13
14 Furthermore, the theoretical model is not able to tell us whether policy measures do have
15
16 an effect, at all, and how these measures have to be designed in order to be most
17
18 effective. The effect of policy measures is represented in the model by parameters. The
19
20 size of these parameters is an empirical question that is not treated in this paper.
21
22

23
24 The theoretical results are summarised in Table 3. There is only one measure which seem
25
26 to be adequate in all stages of the cluster life-cycle: public research. For all other
27
28 measures we were able to find stages in which they should be applied and stages in which
29
30 they can be expected to have no effect. We also found that policy measures are, in
31
32 general, most effective in the initial phase and at the beginning of the expansion phase.
33
34 They also might help to avoid the decline of an existing cluster. Triggering the emergence
35
36 of a cluster in the mature phase is possible but most unlikely since it requires severe policy
37
38 intervention with no guarantee of success.
39
40
41
42

43
44 Besides public research, in the initial phase, the support of start-ups, private R&D and
45
46 networking and cooperation should be the measures of choice. This is very well in line with
47
48 the approaches that are taken in reality as listed in Table 1.
49
50

51
52 In the expansion phase, our theoretical analysis suggests to provide education, public
53
54 research, infrastructure and other supportive local conditions as well as to support start-up
55
56 activities. This differs from the empirical findings. In this stage of development, most
57
58 cluster policies focus on education, start-up activities and networking (see Table 1). Hence,
59
60 there is some overlap. However, public research and local conditions are less frequently
addressed by policy than the theoretical analysis suggests, while networking is supported,

1
2 although our analysis does not show the effectiveness of this measure.
3
4

5 Talking about networking, we have to be cautious with our interpretation of the model's
6
7 results. We only modelled the direct effects of networks on the growth of firms. For this
8
9 kind of networking, we do not find effects in the expansion phase of the cluster life-cycle.
10
11 Other kinds of networking, for example supporting start-up activities, might well be
12
13 adequate in this stage.
14
15
16
17
18
19

20 Table 3: Effects of various policy measures in the different phases of the cluster life-cycle
21
22 according to the theoretical model
23
24
25
26
27

28 In the mature phase, we find that the emergence of clusters is a rather rare event. Hence,
29
30 policy measures that try to make the emergence of clusters more likely are rarely
31
32 successful in this stage. Three measures can prevent existing clusters from
33
34 disappearance: public research, supporting private R&D, supporting networking and
35
36 cooperation. Especially public research and the support of networking are measures
37
38 frequently applied in reality (Table 1). However, we find that education and improving local
39
40 conditions are further measures applied in this stage. Our theoretical analysis implies that
41
42 these measures might make the (re-)emergence of clusters more likely but that this is, in
43
44 general, a quite rare event.
45
46
47
48
49
50
51
52

53 V. Conclusion

54
55 This paper examines the effects of policy measures applied in the context of clusters A)
56
57 with respect to the different stages of the cluster life-cycle and B) their dependence on the
58
59 cluster's life-cycle stage. We use two approaches. First, the literature on policy measures
60
that are applied in the context of clustering is scanned for the kind of measures that are

1
2 applied in the different stages of the cluster life-cycle. Second, we set up a mathematical
3
4 model that describes the dynamics of clustering. The parameters are estimated
5
6 empirically; moreover, the parameters' dependence on the life-cycle stages is identified.
7
8 Afterwards, the resulting model is used to study the impact of the various policy measures
9
10 in the different life-cycle stages of clusters.
11
12

13
14 We find that the literature rarely addresses the question of how policy measures depend
15
16 on the life-cycle stages explicitly. Nevertheless, the literature implicitly provides some
17
18 insights about what measure should be used at which stage. In total, we study six different
19
20 policy categories: education, public research, support of R&D, support of start-ups, support
21
22 of networks and cooperation, and other local conditions. The insights from literature
23
24 distinguish these measures further.
25
26
27

28
29 The model's results do partly match the findings from the literature. However, the two
30
31 approaches have a different perspective. While the mathematical model helps to estimate
32
33 the strength of the impact of each policy measure with respect to the different stages of the
34
35 cluster life-cycle, the literature gives information about how measures should be designed
36
37 in each life-cycle stage. Both information sources seems to be very valuable for policy
38
39 makers.
40
41
42

43
44 Education and the improvement of local conditions show the strongest impact in the
45
46 expansion phase. In this and other early phases, the literature recommends general
47
48 training while in more mature phases training for a specialized labour force seems to be
49
50 more important. Supportive services are usually provided in the mature phase. In the
51
52 context of the model, this can be seen as improving local conditions. This implies that the
53
54 current policy is not in line with our theoretical findings. However, as mentioned above, we
55
56 have to be careful with such an interpretation since the model might not represent the
57
58 effects of such policy measures correctly.
59
60

Public research seems to have a strong impact during the whole cluster life-cycle.

1
2 However, the emergence of a cluster can probably not be triggered in the mature phase of
3
4 the industrial life-cycle. The literature recommends establishing research institutes
5
6 especially in the initial and the mature stages, with a stronger focus on the initial phase.
7
8 This does only partially correspond to the theoretical findings.
9

10
11 In our model examination, the support of private R&D as well as the support of networks
12
13 and cooperation is found to have the strongest impact in the initial and mature phases.
14
15 The literature qualifies this by arguing for different forms of this measure in the various life-
16
17 cycle phases. In the initial phase, it is recommended to support cooperation and private
18
19 R&D. Coordination, the set-up of networks and the support of screening processes for
20
21 technologies are said to be adequate measures in the expansion phase. In the mature
22
23 phase, the focus should shift to the renewal of networks.
24
25

26
27 According to our model analysis, supporting start-up activities is most effective in the early
28
29 phases of the cluster life-cycle. It also plays a less important role in the mature phase
30
31 according to the literature. However, the literature distinguishes between promoting and
32
33 funding start-ups, which is more important in the beginning, and supporting spin-offs,
34
35 which seems to be more important in the expansion phase.
36
37

38
39 This paper is the first that combines two perspectives in order to answer the question of
40
41 which policy measure is most adequate in which phase of the cluster life-cycle. Of course,
42
43 this paper is only a first step. It can be expected that more policy evaluation will be
44
45 conducted in the future so that more evidence will become available. The paper's
46
47 theoretical examination is based on a mathematical model and knowledge about the
48
49 parameters in this model. Estimates for all parameters for each life-cycle stage would allow
50
51 for calculating the impacts of policy measure in more detail. Further studies of industries
52
53 and their development over time would be necessary to obtain such estimates. This is
54
55 another interesting path for further research.
56
57
58
59
60

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Acknowledgements:

We would like to thank Dirk Fornahl as well as other participants of the EMAEE Conference 2009 for helpful comments and suggestions on an earlier draft of this paper. The article has also benefited from detailed comments of two anonymous referees. The usual disclaimers apply.

For Peer Review Only

References

AUDRETSCH D. B. and FELDMAN M. P. (1996) Innovative clusters and the industry life cycle, *Review of Industrial Organization* 11, 253-273.

AUDRETSCH D. B. and LEHMANN E. E. (2006) The role of clusters in knowledge creation and diffusion: an institutional perspective, in ASHEIM B., COOKE P. and MARTIN R. (Eds) *Clusters and Regional Development. Critical reflections and explorations*, pp. 188-197. Routledge, New York.

ANDERSSON T., SERGER S., SÖRVIK J. and HANSSON E. (2004) *The Cluster Policies Whitebook*. IKED: Malmö.

ARTHUR W. B. (1994) *Increasing Returns and Path Dependence in the Economy*. University of Michigan Press, Ann Arbor.

BATHELT H., MALMBERG A., MASKELL P. (2004) Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation, *Progress in Human Geography*, 28, 31-56.

BATHELT H. and DEWALD U. (2008) Ansatzpunkte einer relationalen Regionalpolitik und Clusterförderung, *Zeitschrift für Wirtschaftsgeographie*, 53 (2-3), 129-145.

BORRÁS S. and TSAGDIS D. (2008) *Cluster Policies in Europe. Firms, Institutions, and Governance*. Edward Elgar, Cheltenham, Northampton.

BOSCHMA R. and WENTING R. (2007) The spatial evolution of the British automobile industry: Does location matter?, *Industrial and Corporate Change*, 16, 213-238.

BRENNER T. (2001) *Self-Organisation, Local Symbiosis of Firms and the Life Cycle of Localised Industrial Clusters*, Papers on Economics & Evolution #0103, Max Planck Institute of Economics, Jena.

BRENNER T. (2006) *An Identification of Local Industrial Clusters in Germany*, Regional

1
2 Studies, 40, 991-1004.

3
4
5 BRENNER T. (2008) Cluster dynamics and policy implications, *Zeitschrift für*
6
7 *Wirtschaftsgeographie*, 53 (2-3), 146-162.

8
9
10 BRENNER T. and BRÖKEL T. (2009) Methodological Issues in Measuring Innovation
11
12 Performance of Spatial Units, Working Papers on Innovation and Space #01.09,
13
14 Department of Economic Geography, Philipps-University Marburg, Marburg.

15
16
17 BRENNER T. and FORNAHL D. (2008) Regional Path-Dependence in Start-up Activity,
18
19 Papers in Evolutionary Economic Geography #08.12, University of Utrecht, Utrecht.

20
21
22 BRENNER T. and MÜHLIG A. (2007) Factors and Mechanisms Causing the Emergence of
23
24 Local Industrial Clusters - A Meta-Study of 159 Cases, Papers on Economics & Evolution
25
26 #0723, Max Planck Institute of Economics, Jena.

27
28
29
30 BRUSCO S. (1990) The idea of the Industrial District: Its genesis, in PYKE F., BECATTINI,
31
32 G. and SENGENBERGER W. (Eds) *Industrial Districts and Inter-firm Co-operation in Italy*,
33
34 pp.10-20. International Institute for Labour Studies, Geneva.

35
36
37
38 BUSOM I. (1999) An Empirical Evaluation of the Effects of R&D Subsidies, Burch Center
39
40 Working Paper No. B99/05, Department of Economics, University of California, Berkeley.

41
42
43 CHESHIRE P. (2003) Territorial Competition: Lessons for (Innovation) Policy, in BRÖCKER
44
45 J., DOHSE D. and SOLTWEDEL R. (Eds) *Innovation Clusters and Interregional*
46
47 *Competition*, pp. 331-347. Springer, Heidelberg, Berlin, New York.

48
49
50
51 DINNETZ M. (2007) Country Report: Sweden. Oxford Research AS, Frederiksberg.

52
53
54 DTI (2004) A Practical Guide to Cluster Development. A Report to the Department of Trade
55
56 and Industry and the English RDAs by Ecotec Research & Consulting. Ecotec,
57
58 Birmingham.

- 1
2 ENICHLMAIR C. and OBERHOLZNER T. (2007) Country Report: Austria. Oxford
3
4 Research AS, Frederiksberg.
5
6
7 ENRIGHT M. (2003) Regional Cluster: What We Know and What We Should Know, in
8
9 BRÖCKER J., DOHSE D. and SOLTWEDEL R. (Eds) Innovation Clusters and
10
11 Interregional Competition, pp. 99-129. Springer, Heidelberg, Berlin, New York.
12
13
14 EUROPEAN COMMISSION (2008) The concept of clusters and cluster policies and their
15
16 role for competitiveness and innovation: Main statistical results and lessons learned.
17
18 Commission Staff Working Document SEC (2008) 2637, Europe INNOVA / PRO INNO
19
20 Europe paper N° 9. European Communities, Luxembourg.
21
22
23 FOUNDATION FOR ENTREPRENEURSHIP DEVELOPMENT (2007) Country Report:
24
25 Bulgaria. Oxford Research AS, Frederiksberg.
26
27
28 FRITSCH M. and SLAVTCHEV V. (2005) The role of regional knowledge sources for
29
30 innovation – An empirical assessment. Working Paper 15/2005, Faculty of Economics and
31
32 Business Administration, Technical University Bergakademie Freiberg, Freiberg.
33
34
35 FROMHOLD-EISEBITH M. and EISEBITH G. (2005) How to institutionalize innovative
36
37 clusters? Comparing explicit top-down and implicit bottom-up approaches, Research
38
39 Policy, 34, 1250-1268.
40
41
42
43 GLAESER E., KALLAL H., SCHEINKMAN J. and SHLEIFER A. (1992) Growth in Cities,
44
45 Journal of Political Economy, 100 (6), 1126-1152.
46
47
48
49 HAUSER C. (2007) Country Report: Germany. Oxford Research AS, Frederiksberg.
50
51
52
53 HENDERSON V., KUNCORO A. and TURNER M. (1995) Industrial Development in Cities,
54
55 Journal of Political Economy, 103 (5), 1067-1090.
56
57
58 HOSPERS G. and BEUGELSDIJK S. (2002) Regional Cluster Policies: Learning by
59
60 Comparing?, *Kyklos*, 55, 381-402.
- HUGGINS R. (2008) The Evolution of Knowledge Clusters: Progress and Policy, *Economic*

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Development Quarterly, 22, 277-289.

JAFFE A. (1999) Measurement Issues, in BRANSCOMB L. and KELLER J. (Eds) Investing in Innovation. Creating a research and innovation policy that works, pp.64-84. MIT Press Cambridge, London.

KIESE M. (2008) Mind the Gap. Regionale Clusterpolitik im Spannungsfeld von Wissenschaft, Politik und Praxis aus der Perspektive der Neuen Politischen Ökonomie, Zeitschrift für Wirtschaftsgeographie, 53 (2-3), 129-145.

KLEPPER S. (1997) Industry Life Cycles, Industrial and Corporate Change, 6, 145-181.

KLEPPER S. (2007) The evolution of geographic structures in new industries, in FRENKEN K. (Eds) Applied evolutionary economics and economic geography, pp. 69-92. Edward Elgar, Cheltenham.

KOSCHATZKY K. (2005) The regionalization of innovation policy: new options for regional change?, in FUCHS G. and SHAPIRA P. (Eds) Rethinking Regional Innovation and Change. Path Dependency or Regional Breakthrough?, pp. 291- 312. Springer, New York.

LONGHI C. (1999) Networks, Collective Learning and Technology Development in Innovative High Technology Regions: The Case of Sophia-Antipolis, Regional Studies, 33 (4), 333-342.

LUNDEQUIST P. and POWER D. (2002) Putting Porter into Practice? Practices of Regional Cluster Building: Evidence from Sweden, European Planning Studies, 10, 685-704.

MAGGIONI M. (2004) The Rise and Fall of Industrial Clusters: Technology and the Life Cycle of Regions, Document de treball 2004/6, Universitat de Barcelona, Barcelona.

MARTIN R. and SUNLEY P. (2003) Deconstructing clusters: Chaotic concept of policy panacea?, Journal of Economic Geography, 3, 5-35.

- 1
2 MAS G. (2007) Country Report: United Kingdom. Oxford Research AS, Frederiksberg.
3
4
5 MASKELL P. and KEBIR L. (2006) What qualifies a cluster theory?, in ASHEIM B.,
6
7 COOKE P. and MARTIN R. (Eds) Clusters and Regional Development. Critical reflections
8
9 and explorations, pp. 30-49. Routledge, New York.
10
11
12 MENZEL M. and FORNAHL D. (2007) Cluster Life Cycles-Dimensions and Rationales of
13
14 Cluster Development, Jena Economic Research Papers, 2007-076, Friedrich-Schiller-
15
16 University and Max Planck Institute of Economics, Jena.
17
18
19 MÜLLER A. (2007) Country Report: Spain. Oxford Research AS, Frederiksberg.
20
21
22 PAPADOPOULOS C. (2007) Country Report: Cyprus. Oxford Research AS,
23
24 Frederiksberg.
25
26
27 PORTER M. E. (1990) The competitive advantage of nations. Edward Elgar, New York.
28
29
30 PORTER M. E. (1998a) On Competition. Harvard Business School, Boston.
31
32
33 PORTER M. E. (1998b) Clusters and the new economics of competition, Harvard
34
35 Business Review, November-December, 77-90.
36
37
38 PORTER M. E. (2003) The Economic Performance of Regions, Regional Studies, 37, 549-
39
40 578.
41
42
43 RAINES P. (2000) Developing Cluster Policies in Seven European Regions, Regional and
44
45 Industrial Policy Research Paper, 42, European Policies Research Centre, University of
46
47 Strathclyde, Glasgow.
48
49
50
51 ROELANDT T. J. A. and DEN HERTOOG P. (1999) Cluster Analysis and Cluster-Based
52
53 Policy Making: The State of The Art, in OECD (Eds) Boosting Innovation: The Cluster
54
55 Approach, pp. 413-427. OECD, Paris.
56
57
58
59 SCHLUMP C. and BRENNER T. (2010) University Education, Public Research and
60
Employment Growth in Regions – An Empirical Study of Germany. Working Paper on

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Innovation and Space, # 02.10, Department of Economic Geography, Philipps-University Marburg, Marburg.

SCHOU S. (2007) Country Report: Denmark. Oxford Research AS, Frederiksberg.

SFORZI F. (1990) The quantitative importance of Marshallian industrial districts in the Italian economy, in PYKE F., BECATTINI G. and SENGENBERGER W. (Eds) Industrial Districts and Inter-firm Co-operation in Italy, pp.75-107. International Institute for Labour Studies, Geneva.

SMALLBONE D., NORTH D. and VICKERS I. (2003) The role and characteristics of SMEs in innovation, in ASHEIM B., ISAKSEN A., NAUWELAERS C. and TÖDTLING F. (Eds) Regional Innovation Policy For Small-Medium Enterprises, pp. 3-20. Edward Elgar, Cheltenham, Northampton.

SÖLVELL Ö., LINDQUIST G., KETELS C. (2003) The Cluster Initiatives Greenbook. Ivory Tower, Stockholm.

STERNBERG R. (2003) New Firms, Regional Development and the Cluster Approach – What Can Technology Policies Achieve?, in BRÖCKER J., DOHSE D. and SOLTWEDEL R. (Eds) Innovation Clusters and Interregional Competition, pp. 347-372. Springer, Heidelberg, Berlin, New York.

STERNBERG R. and LITZENBERGER T. (2004) Regional Clusters in Germany: Their Geography and their Relevance for Entrepreneurial Activities, European Planning Studies, 12, 767-792.

VAN KLINK A. and DE LANGEN P. (2001) Cycles in industrial clusters: The case of the shipbuilding industry in the Northern Netherlands, Tijdschrift Voor Economische En Sociale Geografie, 92, 449-463.

VAN DER LINDE C. (2003) The Demography of Clusters – Findings from the Cluster Meta-Study, in BRÖCKER J., DOHSE D. and SOLTWEDEL R. (Eds) Innovation Clusters

1
2 and Interregional Competition, pp.130-149. Springer, Heidelberg, Berlin, New York.
3

4
5 WOLFE D. A. and GERTLER M. S. (2006) Local Antecedents and Trigger Events: Policy
6
7 Implications of Path Dependence for Cluster Formation, in BRAUNERHJELM P. and
8
9 FELDMAN M. (Eds) Cluster Genesis. Technology-Based Industrial Development, pp. 243-
10
11 263. University Press, Oxford.
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Appendix

List of parameters:

Table A.1: List of the parameters with their median estimation (for seven empirically examined industries in Germany), the theoretical prediction of their relative strength (according to Section II.1) and information whether the theoretical prediction is confirmed by the empirical study. If the empirical estimation was not possible or a parameter does not change during the cluster life-cycle, “-” is used

Equations:

$$\log(e_{t+1}) - \log(e_t) = \log \left[\left(\gamma_{e,e} + \frac{\gamma_{e,s} \cdot \gamma_{s,e}}{1 + \exp[\varphi_{s,0} - \varphi_{s,f} \cdot f_{s,t}]} \right) \cdot e_t^{(\gamma_{e,q} + \gamma_{e,i} + \gamma_{e,x} \cdot \gamma_{x,e})} \right. \\ \left. + \left(\frac{\gamma_{e,l} \cdot l_t + \gamma_{e,r} \cdot r_t + \gamma_{e,f} \cdot f_{e,t}}{1 + \exp[\varphi_{s,0} - \varphi_{s,f} \cdot f_{s,t}]} + \frac{\gamma_{e,s} \cdot \gamma_{s,l} \cdot l_t + \gamma_{e,s} \cdot \gamma_{s,r} \cdot r_t + \gamma_{e,s} \cdot \gamma_{s,p} \cdot p_t}{1 + \exp[\varphi_{s,0} - \varphi_{s,f} \cdot f_{s,t}]} \right) \cdot e_t^{(\gamma_{e,q} + \gamma_{e,i} + \gamma_{e,x} - 1)} \right] \\ + \log \left[\left(\frac{p_t - e_t}{p_t} \right)^{\gamma_{e,p}} \right] + \log \left[\left(\frac{E_{glob,t}}{e_{glob,t} \cdot E_t} \right)^{\gamma_{e,q}} \cdot m_t^{\gamma_{e,m}} \cdot \left(\frac{v_{i,e}}{1 + \exp[v_{i,0} - (v_{i,r} \cdot r_t + v_{i,f} \cdot f_{i,t})]} \right)^{\gamma_{e,i}} \right. \\ \left. \cdot \left(\frac{v_{x,e}}{1 + \exp[v_{x,0} - v_{x,f} \cdot f_{x,t}]} \right)^{\gamma_{e,x}} \right] \quad (A.1)$$

$$\alpha = \gamma_{e,q} + \gamma_{e,i} + \gamma_{e,x} \cdot \gamma_{x,e} \quad (A.2)$$

$$a_t = \gamma_{e,e} + \frac{\gamma_{e,s} \cdot \varphi_{s,e}}{1 + \exp[\varphi_{s,0} - \varphi_{s,f} \cdot f_{s,t}]} \quad (\text{A.3})$$

$$b_t = \gamma_{e,l} \cdot l_t + \gamma_{e,r} \cdot r_t + \gamma_{e,f} \cdot f_{e,t} + \frac{\gamma_{e,s} \cdot \gamma_{s,l} \cdot l_t + \gamma_{e,s} \cdot \gamma_{s,r} \cdot r_t + \gamma_{e,s} \cdot \gamma_{s,p} \cdot p_t}{1 + \exp[\varphi_{s,0} - \varphi_{s,f} \cdot f_{s,t}]} \quad (\text{A.4})$$

$$c_t = \left[\left(\frac{E_{glob,t}}{e_{glob,t} \cdot E_t} \right)^{\gamma_{e,q}} \cdot m_t^{\gamma_{e,m}} \cdot \left(\frac{v_{i,e}}{1 + \exp[v_{i,0} - (v_{i,r} \cdot r_t + v_{i,f} \cdot f_{i,t})]} \right)^{\gamma_{e,i}} \right. \\ \left. \cdot \left(\frac{v_{x,e}}{1 + \exp[v_{x,0} - v_{x,f} \cdot f_{x,t}]} \right)^{\gamma_{e,x}} \right] \quad (\text{A.5})$$

Median values of abbreviations:

Table A.2: Dependence of terms α , a_t , b_t and c_t on the stages of the cluster life-cycle

Proof of Proposition 1:

In order to identify the stable states of the dynamics given by Equation (10), we first have to determine the stationary states, meaning the states with $de_t/dt=0$. These states are given by

$$\log \left[c_t \cdot (a_t \cdot e_t^\alpha + b_t \cdot e_t^{\alpha-1}) \cdot \left(\frac{p_t - e_t}{p_t} \right)^{\gamma_{e,p}} \right] = 0. \quad (\text{A.6})$$

Let us first consider $\alpha < 1$. For $e_t \rightarrow 0$ the term above (left-hand side of (A.6)) goes to infinity. For $e_t \rightarrow p_t$ the term above goes to $-\infty$. Furthermore, the term is continuous in e_t . Hence, there is at least one value of e_t for which the term takes a value of 0. If the term has local minima and maxima, there might be more values of e_t for which the term on the left-hand side of (A.6) equals 0. In order to find the local minima and maxima of the left-hand side of

(A.6) we consider the term $L(e_t)$ which is given by Equation (11):

$$L(e_t) = c_t \cdot (a_t \cdot e_t^\alpha + b_t \cdot e_t^{\alpha-1}) \cdot \left(\frac{p_t - e_t}{p_t} \right)^{\gamma_{e,p}}. \quad (\text{A.7})$$

We look for values of e_t for which the derivative of this term is zero. For small values of e_t , according to Assumption 1, the last term of $L(e_t)$ can be ignored. Hence, a local minima or maxima for small values exists if

$$c_t \cdot (a_t \cdot \alpha \cdot e_t^{\alpha-1} + b_t \cdot (\alpha-1) \cdot e_t^{\alpha-2}) = 0. \quad (\text{A.8})$$

This condition is satisfied for

$$\hat{e}_1 = \frac{b_t \cdot (1-\alpha)}{a_t \cdot \alpha}. \quad (\text{A.9})$$

For large values of e_t , according to Assumption 1, the first term in $L(e_t)$ can be ignored.

Hence, a local minima or maxima for large values exists if

$$c_t \cdot b_t \cdot e_t^{\alpha-1} \cdot \left(\frac{p_t - e_t}{p_t} \right)^{\gamma_{e,p}} \cdot \left(\frac{\alpha-1}{e_t} - \frac{\gamma_{e,p}}{p_t - e_t} \right) = 0. \quad (\text{A.10})$$

This condition is satisfied for

$$\hat{e}_2 = \frac{\alpha-1}{\gamma_{e,p} + \alpha-1} p_t. \quad (\text{A.11})$$

Hence, the term $L(e_t)$ has one local minimum at a value of \hat{e}_1 and one local maximum at a value of \hat{e}_2 . Three situations might result:

1. $L(\hat{e}_2) < 1$, which implies also $L(\hat{e}_1) < 1$: This implies that Equation (A.6) cannot be satisfied for value of e_t larger than \hat{e}_1 . Hence, there is only one stationary state, which is stable for a low value of e_t ($e_t < \hat{e}_1$).
2. $L(\hat{e}_1) < 1$ and $L(\hat{e}_2) > 1$: This implies that Equation (A.6) is satisfied for values of e_t between \hat{e}_1 and \hat{e}_2 as well as for values of e_t smaller than \hat{e}_1 and values of e_t larger than \hat{e}_2 . Hence, there are three stationary states. The lowest ($e_t < \hat{e}_1$) and the highest ($e_t > \hat{e}_2$) of them are stable.

- 1
2
3
4
5
6
7
8
3. $L(\hat{e}_1) > 1$, which implies also $L(\hat{e}_2) > 1$: This implies that Equation (A.6) cannot be satisfied for values of e_t smaller than \hat{e}_2 . Hence, there is only one stationary state, which is stable, for a high value of e_t ($> \hat{e}_2$).

9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

The situation is different if $\alpha > 1$. In this case the term on the left-hand side of (A.6) is $-\infty$ for $e_t \rightarrow 0$ and for $e_t \rightarrow p_t$. This implies that one stable stationary state exists for $\hat{e}_1 = 0$. $L(e_t)$ has no local minima but has a local maximum at \hat{e}_2 given by (A.11). Two different situations result: First, if $L(\hat{e}_2) < 1$, there is only one stable state for $e_t = 0$ as described as situation 1 above. Second, if $L(\hat{e}_2) > 1$, there are three stationary states as described as situation 2 above.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Most relevant phase in the cluster life-cycle	Policy measure
Initial	Start-up promotion (science parks, incubators) Cooperation support (meetings etc.) Development of innovative culture Establishment of laboratories R&D support
Initial/Expansion	Education and training (conferences, learning processes) Networks (informal, institutionalised), joint activities Seed funds, better access to capital, VC Cluster marketing & service provision
Expansion	Screening activities, access to new technology Industrial coordination and cooperation
Expansion/Mature	Spin-off support (financing, collaborations, services)
Mature	Development of human capital, specialized work force Support services Renewal of networks, cooperations Lighthouse projects Set-up of research institutes

Table 1: Policy measures and the time in the cluster life-cycle when they are most relevant

For Peer Review Only

Stage	Dynamics	Conditions
Initial stage	Emergence of a cluster (C)	a_t and c_t rather large
	No emergence of a cluster (A)	a_t and c_t rather small
Expansion stage	Emergence of a cluster (C)	α rather small, b_t rather large
	Stabilisation of the situation (B)	α rather large, b_t rather small
Mature stage	(Re-)emergence of a cluster (C)	α small and b_t and c_t rather large
	Stabilisation of the situation (B)	α and c_t rather large and b_t rather small
	Disappearance of a cluster (A)	c_t not large

Table 2: Model implications for the dynamics in the three stages of the cluster life-cycle

Policy measure	Impact in			
	Initial phase	Expansion phase	Mature phase for	
			Avoiding decline	Triggering emergence
Education	no	yes	No	partly
Public research	yes	yes	Yes	yes
Supporting R&D	yes	no	Yes	partly
Supporting start-ups	yes	yes	No	partly
Supporting networks	yes	no	Yes	partly
Other local conditions	no	yes	No	partly

Table 3: Effects of the various policy measures in the different phases of the cluster life-cycle according to the theoretical model

Parameter	Median	Strength according to the theoretical knowledge (Section II.1) in the different stages			Confirmed by empirical estimations
		Initial stage	Expansion stage	Mature stage	
$\gamma_{e,e}$	0.4	small	very large	medium	No evidence
$\gamma_{e,s}$	112	Very large	large	small	No evidence
$\gamma_{e,l}$	0.96	large	very large	medium	No evidence
$\gamma_{e,r}$	7.9	large	very large	medium	yes
$\gamma_{e,f}$	200	large	medium	medium	No evidence
$\gamma_{e,q}$	0.5	small	large	large	yes
$\gamma_{e,m}$	-	-	-	-	-
$\gamma_{e,i}$	0.001	medium	very large	medium	No evidence
$\gamma_{e,x}$	-	small	very large	very large	-
$\gamma_{e,p}$	2.9	-	-	-	No evidence
$\varphi_{s,p}$	0.02	very large	large	small	yes
$\varphi_{s,e}$	1.14	very large	large	small	yes
$\varphi_{s,l}$	5.4	very large	large	small	No evidence
$\varphi_{s,r}$	4.2	very large	large	small	yes

$\varphi_{s,0}$	7.3	-	-	-	No evidence
$\varphi_{s,f}$	0.1	very large	large	small	No evidence
$v_{i,e}$	55	small	very large	medium	yes
$v_{i,r}$	0	medium	very large	medium	No evidence
$v_{i,x}$	-	small	very large	very large	-
$v_{i,f}$	0.02	medium	very large	medium	No evidence
$v_{i,0}$	8.8	-	-	-	No evidence
$v_{x,e}$	-	small	very large	very large	-
$\gamma_{x,e}$	-	-	-	-	-
$v_{x,f}$	-	small	very large	very large	-
$m_i^{\gamma_{e,m}}$	-	medium	very large	medium	-

Table A.1: List of the parameters with their median estimation (for seven empirically examined industries in Germany), the theoretical prediction of their relative strength (according to Section II.1) and the information whether the theoretical prediction is confirmed by the empirical study. If the empirical estimation was not possible or a parameter does not change during the cluster life-cycle, “-” is used.

Abbreviations	Median	Value according to the theoretical knowledge (Section II.1) in the different stages		
		Initial stage	Expansion stage	Mature stage
α	0.5	small	very large	large
a_t	0.52	very large, but the first term small	large – very large	small
b_t	$1.5 \cdot l_t + 8.3 \cdot r_t + 0.002 \cdot p_t + 200$	large – very large	large – very large, but the last term medium	small - medium
c_t	$0.01 \cdot m_t^{\gamma_{e,m}}$	small - medium	very large	medium, with one part very large

Table A.2: Dependence of the terms α , a_t , b_t and c_t on the stages of the cluster life-cycle

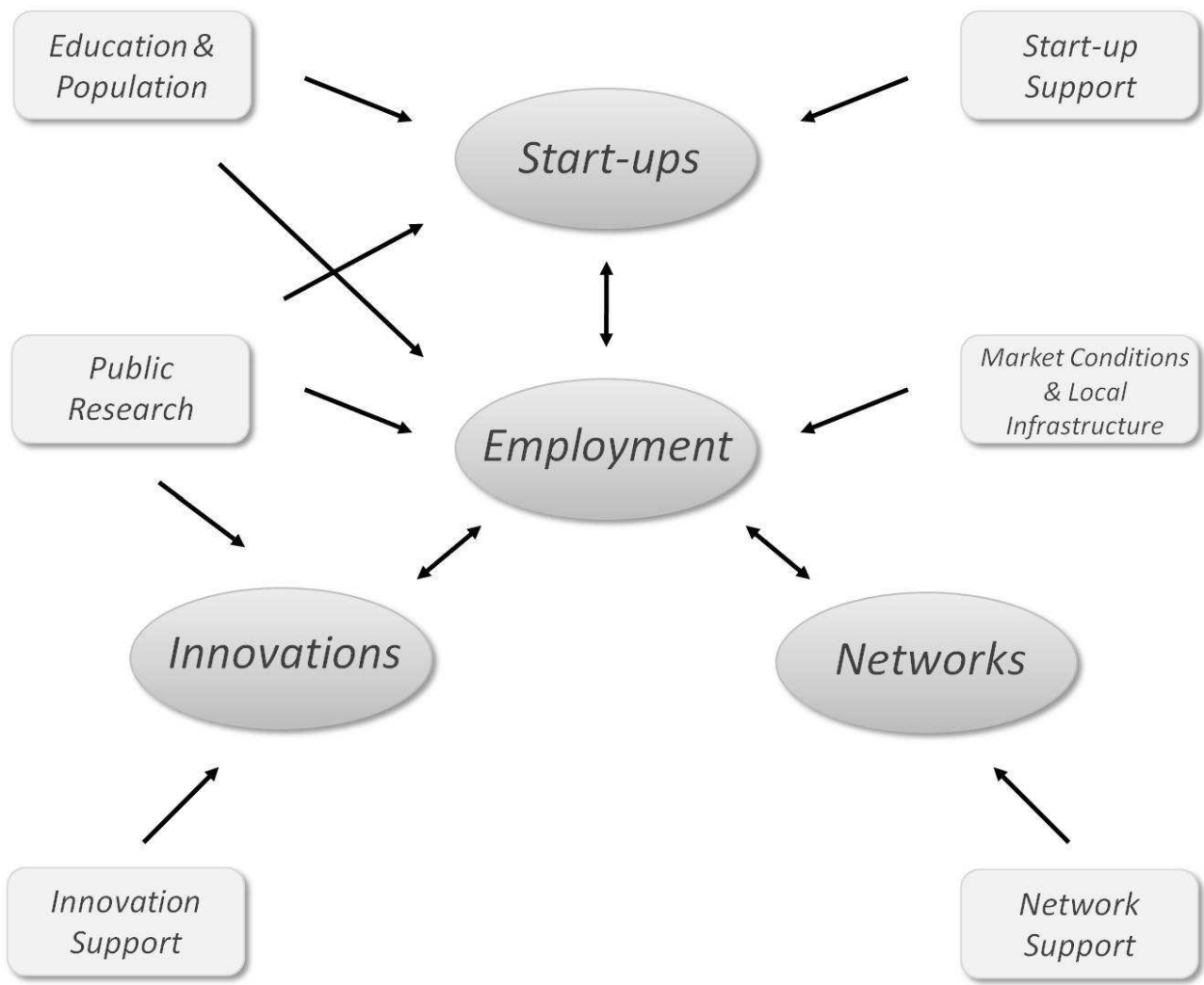


Figure 1: Structure of the mathematical model

View Only

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

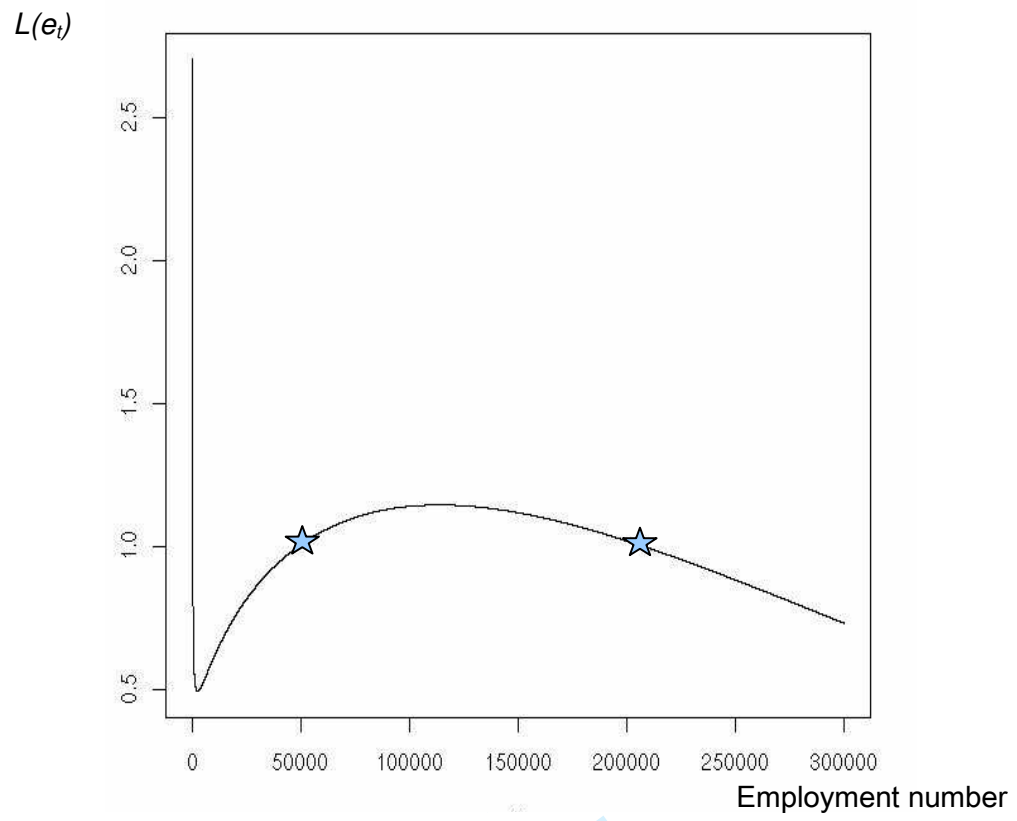


Figure 2: Function $L(e_t)$ for the median parameter values and a region with 800,000 inhabitants.

Review Only