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REGULAR ARTICLE

When does defection pay?

The stability of institutional arrangements in clusters

Kerstin Press

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Abstract The present paper investigates cluster adjustment to changing economic environments by focussing on the role and stability of institutional arrangements in their local culture. It postulates two idealtypical local cultures where firms act in the common (collective) or in their own interest (egoistic). By comparing adjustment performance and stability for both types, the model finds that clusters in very volatile environments are unlikely to exhibit collective local cultures as these are unstable and provide only limited benefits for adjustment performance. Clusters facing more stable environments are more likely to show collective local cultures as these increase adjustment performance and are more stable against individual defection. Both findings suggest that collective local cultures in clusters can be relatively stable for limited environment volatility.

Keywords Clusters · Adjustment · N/K model · Local culture

1 Introduction

Since the works of Brusco (1982), Krugman (1991) or Porter (1990), the phenomenon of non-random spatial concentrations of firms in one or few related industries (often referred to as clusters (Ellison and Glaeser 1997)) has become a prominent topic in economic theory and policy. The existence and success of clusters is usually justified by the benefits conveyed to co-located firms (as compared to isolated enterprises), which encompass (Marshall 1920, pp. 280–284):

K. Press (✉)
Chair of Systems Design, ETH Zurich, 8032 Zurich, Switzerland
e-mail: kpress@ethz.ch

1. Better control of employees, easier communication, and less waste of material due to the (on average) smaller size of establishments.
2. Greater flexibility in product characteristics and output quantities through changing networks of suppliers and end-producers.
3. The emergence of external scale economies (agglomeration externalities) through joint conduct of related activities. These agglomeration externalities include information and knowledge spillovers through inter-firm observation and collaboration; the emergence of pooled labour markets due to immigation and training activity of local firms; as well as scale and specialisation benefits due to a division of labour in production.

In order for agglomeration externalities to emerge, local firms have to overcome a variety of dilemma. Those companies willing to invest in activities contributing to agglomeration externalities are liable to exploitation from free-riders. *"The mysteries of the trade"* will only be *"as it were in the air"* (Marshall 1920, p. 271) and thereby contribute to greater creation and dissemination of knowledge in the cluster if there is an understanding between firms as to what can be done with the knowledge gained from others. Similarly, investment in worker training contributing to a pooled local market for skilled employees is only a viable strategy, if firms can capitalise on this investment; i.e. if the trained worker is not immediately hired away by a competitor. Finally, a division of labour giving rise to specialised suppliers will only emerge if suppliers can trust to sell their inputs at a fair price.[1]

To solve these dilemma situations, clusters develop a *local culture* that acts as a form of governance between firms (Robertson and Langlois 1995). This local culture comprises rules on acceptable business behaviour as well as a mechanism for their enforcement. Usually, it is argued that the rules emerge as agents in the cluster learn from experiences in exchange with others. Geographic proximity facilitates this process, since actors in the same area already share a set of formal institutions such as legislation as well as some general informal institutions like norms deriving from their respective (national or regional) cultural background. As a result, they are more likely to agree on judging specific forms of behaviour as desirable or undesirable (Louch 2000) and more specific local rules would evolve to provide incentives for desirable activities.

To ensure the enforcement of the rules of the local culture, different mechanisms exist: Punishment by more powerful parties in hierarchical clusters, use of formal institutions against defecting agents (Caeldries 1996), or informal collective enforcement. The last mechansim argues that agents in the cluster observe each other's activities[2] and punish defectors by exclusion from all future exchanges (Holländer 1990; Kandel and Lazear 1992; Varian 1990). As agents in the cluster usually interact in a variety of networks (Cappellin 2003), defection in one then entails the risk of losing other

[1] "The one who makes the heads of the pins must be certain of the co-operation of the one who makes the points if he does not want to run the risk of producing pin heads in vain" (List 1909, Book II, Chap. XII, p. 7).

[2] This joint observation and punishment is assisted by geographic proximity: Agents can meet easily due to neglible travel costs and often also interact outside the business sphere.

valuable ties. This greatly increases the cost of defection, ensuring compliance with the rules of the local culture.[3]

Locating in a cluster characterised by agglomeration externalities and a local culture can enhance company performance as is evidenced by a variety of success stories worldwide (see Porter (1990) or Saxenian (1994) among many others). At the same time, the focus on successful clusters neglects that many of the old industrial areas of today were successful clusters in the heyday of their industries. As the technological and economic environment changed, these industrial structures proved unable to adapt and were rendered obsolete (Braunerhjelm et al. 2000; Bresnahan et al. 2001; Grabher 1993; Massey and Meegan 1982). The critical aspect about adaptation in clusters is, that the very drivers of cluster success can become liabilities in the face of change. If agglomeration externalities and a local culture exist, firms are constrained in their adjustment activity. Agglomeration externalities imply that the success of individual activities depends on the actions adopted by others. Additionally, specific rules in the cluster's local culture could rule out necessary adjustment measures as unacceptable business behaviour.

This role of local rules for the adaptability of firms and clusters is emphasised in much of the empirical literature (e.g. Boschma and Lambooy 2002; Cainelli and Zoboli 2004; Lombardi 2003; Saxenian 1994). Regarding insight into the optimum type of local culture, the evidence is however mixed. Some contributions propose that the key to success in clusters is a local culture fostering strong inter-firm competititon (Porter 1990).[4] This notion suggests that clusters with firms acting in their own best interest tend to be particularly successful. Other contributions (Maillat 1998; Pyke et al. 1990) have argued that the blending of social and business ties in clusters or particular attitudes of individuals (Saxenian 1994) could give rise to local cultures prescribing more collective firm behaviour than the standard economic rationale would predict. In this notion, it is argued that clusters with firms selecting strategies to benefit the cluster as a whole perform very well. This type of attitude would ensure that "*the industry as a whole progresses regardless of the fate of any individual firm*" (Saxenian 1994, p. 45).

The notion of collective firm behaviour is a very controversial aspect in the cluster concept, especially when stability and adjustability are concerned. Regarding stability, the question is whether the often informal mechanisms described in the literature (collective observation and punishment) are sufficient to enforce collective behaviour, especially when considering that acting in the interest of the cluster is unlikely to always benefit the firm itself (at least not in the short run). It would take a very accurate

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[3] Such a credible threat of punishment can already be sufficient to enforce co-operation (Fehr and Schmidt 1999).

[4] In this framework, instances of collaboration are also possible. The resulting co-opetition can be structured according to the stage of the value chain as developed by Maskell (2001), where firms offering complementary activities collaborate while those involved in the same value chain stage compete. Co-opetition can also be conditional on time, i.e. firms can collaborate for a while (e.g. during projects) to return to competition afterwards (Grabher 2002; Maskell and Lorenzen 2004). Finally, co-opetition might depend on the type of activity performed. For instance, competing firms can collaborate in order to generate collective resources such as infrastructure or organise political influence (Porter 1990).

detection of defective activity as well as immediate and consequent punishment by all cluster agents in order to enforce this kind of activity.

In changing environments, stability may become an issue as change may affect the detectability of misbehaviour and thereby reduce the enforcability of a collective local culture. Detection may be reduced since clusters do not readily allow for a mapping of the effect of agent activities on her intentions, especially after environmental change. This is due to two aspects. First, cluster activities are conducted by independent agents which share agglomeration externalities between them. As a result, agent activities—even when directed at the benefit of the cluster—do not have to lead to collectively optimal results and adverse effects of agent strategies may be caused by defective behaviour as well as by conflicts between individual actions. Second, environmental change implies that adverse effects can also be due to a mismatch between old strategies and new circumstances. Agents in a cluster facing changing conditions could therefore be tempted to use these detection problems in order to defect from the prescribed collective behaviour and act in their own best interest instead. Any negative effects conveyed by their egoistic activities on other agents might then be blamed on the new environmental conditions.

For agents in the cluster to use this opportunity, defection has to pay, i.e. the payoff associated with egoistic behaviour has to be higher than that of the prescribed collective attitude. Due to agglomeration externalities between agents, this is not necessarily the case. If an agent selects activities that benefit herself at the expense of others in the cluster (e.g. a supplier cutting costs by using cheaper material), this may harm other firms that this very agent depends on (e.g. the corresponding end-producer). As a result, defection could also harm the defector. If it however pays to defect, the next issue is the stability of the overall local culture, i.e. whether a defecting agent can ‘invade’ a population of collectively oriented agents and destabilise a collective local culture. If this is not the case, defection would be sustainable and the local culture would remain stable.

In addition to stability, one has to investigate the role of a local culture for cluster adjustability. In the existing literature, it is sometimes argued that clusters with collective local cultures might be too slow in adjusting to changing economic environments (Brusco 1986; Brusco and Righi 1989; Cainelli and Zoboli 2004; Capecchi 1990; Pyke et al. 1990). This is due to the fact that it takes longer to discover strategies that benefit the entire cluster rather than an individual firm. As a result, the presence of agents acting in their own interest could increase cluster adjustability, i.e. defection might be beneficial for clusters facing changing environments.

The present paper investigates both aspects, thereby shedding light on the stability of collective local cultures and their role in cluster adjustment. It takes two benchmark cases of clusters with collective and egoistic local cultures, i.e. situations where all firms act in the interest of the cluster or in their own interest. Beyond these two cases, the model introduces mixed clusters where some agents act in accordance with the rules prescribing collective behaviour while different and given numbers of agents defect from this consensus. These different cluster types are then exposed to environments with different degrees of volatility. By comparing adjustment performance at the cluster and producer group level, the model provides some insight (at the aggregate level), regarding whether and when defection from a collective local culture pays for agents and their groups, whether this defection destabilises the local culture and whether the presence of defecting agents can help the cluster adjust to environmental changes.

Finding conditions under which defection pays and destabilises an established collective local culture could then assist in explaining a move towards more hierarchical enforcement mechanisms (as has been observed in many Italian districts by Boschma and Lambooy 2002; Cainelli and Zoboli 2004; Lombardi 2003) or highlight the type of environment in which one is particularly likely to find clusters with collective or egoistic local cultures. In order to do so, the paper develops a simulation model based on the N/K method developed by Kauffman (1993). The model includes firms that act in compliance with an established collective local culture as well as those companies that defect from these rules by acting egoistically. It finds that in environments where change is significant, collective local cultures provide only limited benefits to cluster performance. Moreover, when defection pays, it is rarely sustainable and does not help cluster adjustment. In environments where change is smaller yet frequent, collective local cultures increase cluster performance. Individual defection may pay but is usually sustainable and beneficial to cluster adjustment. Both findings suggest that in specific situations, collective behaviour in clusters may well be more stable than is usually acknowledged.

2 The model

The present model integrates a smallest common denominator about the nature of clusters in the existing literature with the aspects of cooperation and defection within a collective local culture.[5] In doing so, it investigates whether defection is possible and to what extent it may even be beneficial for the adjustment performance of the cluster as a whole. This aim is achieved by taking a cluster with a collective local culture and introducing varying numbers of defecting agents. As will be shown in more detail later, agent strategies adhering to and defecting from the local culture have distinct advantages and downsides in adaptation, which will map out differently depending on the setup of the cluster and the volatility of its environment.

2.1 Cluster setup

As was highlighted in the introductory section, clusters are composed of a variety of firms specialising in different stages of the same production process. Due to agglomeration externalities, the activities of a firm can have a positive or negative effect on the outcome of activities conducted by another (e.g. supplier quality impacting on the quality of end-producers). The existence of a collective local culture implies that

[5] While similar to previous studies of organisational adjustment using the same methodology (Dosi et al. 2003; Marengo et al. 2000; Rivkin and Siggelkow 2003; Siggelkow and Levinthal 2003; Siggelkow and Rivkin 2005), the present model's unit of analysis (organisations in a cluster) implies that a number of aspects about agent dynamics differ. This involves the fact that the activities relevant to the cluster are controlled by several, independent agents rather than one firm. Moreover, the lack of central authority in a cluster means that agents do not necessarily arrive at collectively optimal results.

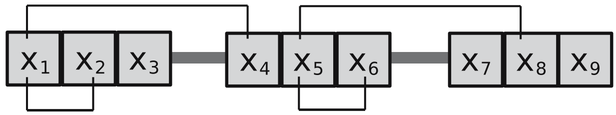

Fig. 1 Intra- ($x_1, x_2/x_5, x_6$) and inter-agent ($x_1, x_4/x_5, x_8$) externalities in a cluster with $N = 9$ value chain activities split into three substrings with $n = 3$

co-operating firms (*altruists*) will favour activities that benefit the cluster as a whole whereas defecting ones (*egoists*) act in their own best interest. The success of any cluster then depends on agent activities, their interplay due to agglomeration externalities as well as the fit of agent and cluster dynamics with the greater economic environment. Changes in this environment therefore also impact on the success of the cluster itself.

In order to account for these aspects, the model uses the N/K methodology developed by Kauffman (1993). The cluster is represented by a local value chain composed of N elements (activities). Each element can take on two states [0; 1], which represent different strategy choices for an activity. The success of these choices is then reflected in the fitness contribution of the activity, which is randomly drawn from a uniform distribution between 0 and 1. All fitness contributions depend on the state of their activity, environmental conditions as well as any positive or negative influences of interdependent activities.

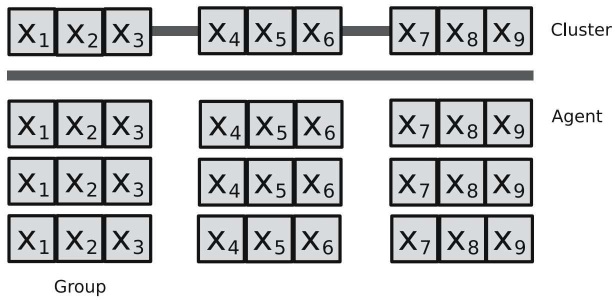

Fig. 2 Model setup: Three agents form one group conducting the activities belonging to one substring (e.g. x_1-x_3)

When modelling clusters as N/K systems, one has to take into account that the different activities in the cluster's value chain are controlled by several independent organisations (also: actors, agents). This gives rise to two different types of interdependencies (see also Fig. 1): Intra-agent externalities affect activities controlled by one agent and reflect that certain strategy choices (e.g. research and production) need to be aligned to produce good results. In clusters, moreover, interdependencies can exist between activities controlled by different agents (inter-agent externalities).[6] This mirrors the effects of agglomeration externalities. Due to inter-agent externalities, strategy choices by one agent may feed back onto the success (=fitness) of others. With the existence of these externalities, individual activities may thus create unexpected or unintended collective results (Axelrod and Cohen 1999).

[6] In the N/K model, intra-agent externalities are usually denoted by the parameter K and inter-agent ones by C. Both measure the average number of interdependent elements.

In addition, clusters usually host several firms producing a certain sub-product. The model includes this fact by having different *groups* of agents representing one stage in the value chain (see also Fig. 2). Each of these groups contains several agents (three in Fig. 2), that all conduct the activities (e.g. x_1-x_3) in the respective substring.[7]

2.2 Environment

In the N/K framework, each of the 2^N configurations of value chain activities has a different fitness value (equaling the mean value of the fitness contributions of all activity states). Taken together, they form the *fitness landscape* of the cluster. As the fitness values of elements are determined by environmental conditions, any change in the cluster's environment will be represented as an alteration of the fitness landscape. Depending on how agent behaviour and cluster structure work together, the cluster can fare better or worse in adjusting to these changes, i.e. it can discover fitter or worse new configurations after the change in the landscape occurred.

The environment's volatility is distinguished according to the extent of external perturbations and their frequency. There are *shock* environments in which the entire fitness landscape changes after a certain time as well as *disturbance* environments, where only part of the landscape is altered (for detail, see Sect. 3). In addition, the time allowed for cluster adjustment differs. In *fast* environments, it equals 300 simulation steps and in *slow* environments, 600 steps precede any change event. Four environmental constellations are therefore investigated: Volatile environments encompass slow and fast shocks while more stable environments are characterised by slow and fast disturbances.

2.3 Dynamics

The model's dynamics map out as follows. In each simulation step, all cluster agents seek better configurations by altering the states of the elements they control (*search*). Agents then *test* if the new configuration is better than the previous one according to different criteria that will represent the local culture in the cluster. If the new configuration constitutes an improvement in expected fitness, it is selected. This test and selection is done assuming that other agents in the cluster do not change their activities: Due to uncertainties about other's future activities and the exact interdependence with them, actors are better off selecting strategies that would work well in the current context. This means that depending on the actions undertaken by others, individual activities may miss their goals or lead to unanticipated aggregate effects.

After selecting a configuration, agents engage in a *bidding* process to be chosen to represent their producer group. This mirrors the learning from observation at the horizontal level of the cluster as emphasised by Maskell (2001); Porter (1990) among others: Competing firms facing the same locational conditions can easily observe, whether a competitor has found a good strategy and then imitate it. As a result, best

[7] This implementation ascertains that all agents in one stage of the value chain (e.g. all end producers) control the same range of activities. Moreover, there is no overlap in activities between value chain stages.

practice will quickly diffuse in groups of competing cluster firms. Since agent activities are interdependent, best practice corresponds to strategies that work well within the context of other cluster agent activities. As a result, the agent with the best configuration regarding expected fitness of the entire cluster is chosen to represent her group. In the final stage of each simulation step, all chosen agent configurations are taken together, determining the actual fitness of the cluster (the value chain) and its agent groups.

The cluster's local culture impacts on agent strategy selection by determining to what extent agents take the effect of their actions on others into account when testing a new configuration. The two types of agents investigated here are *altruists* (agents adhering to a collective local culture by acting the interest of the cluster) and *egoists* (agents defecting from the local culture by acting only in their own best interest). To single out the influence of both agent types on the performance of clusters and their constituent agent groups, the simulation model accounts for seven different cluster types. It uses the benchmark cases of clusters composed of only altruistic agents (Coll) and only defecting (Ego) agents. In between both cases, different numbers of egoistic agents are introduced into the first group of producers. As a result, the setups of Ego1 to Ego5 describe settings where there are 1-5 egoistic (defecting) agents located in the first group.

The difference between the two agent types is that altruists select new configurations only if they improve the expected average fitness of the entire cluster whereas egoists select any configuration that provides a higher expected fitness for the subset of activities that they control. This difference in agent behaviour will matter for the dynamics of clusters when understood as N/K systems.[8] Altruists trying to improve the fitness of all N elements are less likely to find improvements in their configuration than egoists aiming to increase the fitness of their n elements (Press 2006). The modifications found by altruistic agents will however tend to be better for the cluster: As altruists do not ignore externalities of their activities on other agents, they tend to propose better configurations for the cluster as a whole. The opposite hols for egoists implying that there is a tradeoff in speed and efficiency between both agent types.

These aspects lead to the following propositions about the advantages and downsides of altruists and egoists. Altruists will be slower in encountering superior configurations, i.e. they generate fewer changes in their substring. The configurations that are selected will however be better for the cluster as a whole. Egoists in turn are faster in encountering superior configurations, i.e. they generate more changes in their substring. The configurations proposed may however be worse for the cluster as a whole. Having defection in the cluster will therefore increase the speed of adjustment to any change in the fitness landscape, while adversely influencing the results and stability of adjustment processes. Both aspects will materialise to differing extent depending on the cluster's structure and environmental conditions.

[8] As was found by previous work (Frenken 2006; Kauffman 1993; Marengo et al. 2000), the dynamics of any N/K system depend on three aspects. The structure of the system (size and interdependence), agent search, and agent selection mechanisms. By keeping structure and search identical, the model can investigate the effect of selection (differing according to agent adherence to or defection from the local culture) on the performance of the cluster and its groups.

Table 1 Intra- (x) and inter-agent (**x**) externalities a cluster with $N = 9$ value chain activities split into three substrings with $n = 3$ and a block distribution of interdependencies of length $l = 2$ and $l = 4$

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9
x_1	-	x							
x_2	x	-							
x_3			-	**x**					
x_4			**x**	-					
x_5					-	x			
x_6					x	-			
x_7							-	x	
x_8							x	-	
x_9									x

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9
x_1	-	x	x	**x**					
x_2	x	-	x	**x**					
x_3	x	x	-	**x**					
x_4	**x**	**x**	**x**	-					
x_5					-	x	**x**	**x**	
x_6					x	-	**x**	**x**	
x_7					**x**	**x**	-	x	
x_8					**x**	**x**	x	-	
x_9									x

Regarding cluster structure, the degree of interdependence between agents is key. In the present model, interdependencies between activites are argued to follow a block distribution with varying block length (see also Table 1). All elements in a block are mutually interdependent.[9] Since the division of labour in the cluster does not need to coincide with the block length $n \neq l$, some interdependencies reside at the level of agents (denoted by x in Table 1) while others connect the activities of different agents (denoted by **x**).

With greater interdependence in the production process (higher l), the extent of cross-agent externalities increases for any given division of labour (see also Table 1). To capture this effect, the model assumes three different levels of interdependence between production activities: *Low* ($l = 4$), *medium* ($l = 8$) and *high* interdependence ($l = 12$).[10] Growing inter-agent externalities lead to greater benefits for collective local cultures: Altruistic agents internalise these externalities into their choice of strategy, which will give better results as the role of inter-agent interdependence increases. Moreover, these agents are less likely to select modifications encountered by their search activity as the average expected fitness of a greater number of elements has to be improved. This implies that altruists will tend to change their configuration less frequently than egoists. This relative 'inactivity' can be beneficial as growing interdependence between agents means that changes in configuration by one actor impact more strongly on the fitness of other agents (Kauffman 1993). Frequent changes in strategy could therefore disturb others, inducing them to respond by changing their configuration as well. Taken together, this can have a destabilising impact on the cluster's adjustment process.

Proposition 1 *In clusters with medium or high interdependence, altruists will be better for cluster adjustability than egoists.*

Regarding environmental conditions, the frequency of change events will be decisive. The greater time required for altruistic agents to encounter superior modifications

[9] This setup yields a fully decomposable system as defined by Simon (2002). However, following Dosi et al. (2003), the division of labour does not follow the size of the blocks here.

[10] In the low interdependence case, blocks of $l = 4$ activities are mutually interdependent. Each activity thus influences its own fitness contribution as well as that of $l - 1 = 3$ other activities. Similarly, in the medium and high interdependence case, each activity impacts on 7 and 11 other activites. These interdependence structures are implemented for a cluster with $N = 24$ activities split into four substrings with $n = 6$ activities each.

could be a disadvantage in situation where environmental change is relatively fast. As a result, the greater speed of egoists will benefit cluster adjustment in situations where the time left to adjust to a change event is short. Moreover, the extent of change will matter for the relative performance of the different cluster types. As was highlighted above, altruists propose strategies that are better for the cluster as a whole while egoists are faster in finding (on average) inferior configurations. In environments where change is only partial (disturbance environments), the good configurations found by altruists could persist over a longer time than in shock environments where the entire fitness landscape changes.

Proposition 2 *The presence of more altruistic agents is of greater benefit to cluster adjustment if the environment is relatively stable.*

3 Results

The following simulations consider a cluster with $N = 24$ elements split evenly between four groups of producers.[11] Each group of producers hosts five agents that all conduct the $n = 6$ activities in their respective substring. Simulations were run for slow and fast shock environments where the fitness of all 24 elements was altered after 600 and 300 simulation steps. Slow and fast disturbance environments correspond to situations where the fitness of six randomly selected elements in the fitness landscape is changed after 600 and 300 simulation steps. Both types of environments were investigated for clusters with low, medium and high interdependence in their production process. For each setting, 100 change events were simulated to account for performances in the majority of cases. In shock environments, the results reported here correspond to the averages and standard deviations of fitness values over the 600 simulation steps, which were averaged over all 100 simulations (each representing one change event). In disturbance environments, average fitness and standard deviation were averaged over the length of one simulation run, featuring 100 change events. Both values were determined at the level of the entire cluster as well as for each producer group.

Three important criteria for the impact of defecting (egoistic) agents on their group and the cluster are put forth. First, defection has to *pay* for agents, i.e. the fitness of the group hosting egoistic agents has to be higher than in the benchmark case where all agents are altruistic. Second, a stable collective local culture requires that defection is *sustainable*. Sustainable defection here is defined as situations where the presence of egoistic agents in the first group does not decrease the fitness of the second group too extremely. As both groups are interdependent (akin to the setting described in Table 1), egoistic behaviour in the first group is likely to reduce the fitness of the second one. If the fitness obtained by the second group were below the level obtainable in the situation where all agents in the cluster defect (Ego), we would face a prisonner's dilemma payoff situation and defection would become the dominant strategy in the

[11] The simulation model was implemented and run with the Laboratory of Simulation Development (LSD) platform developed by Marco Valente. For detail on LSD, see http://www.business.aau.dk/~mv/Lsd/lsd.html.

cluster. In this case, the collective local culture is destroyed by an invasion of egoists and defection will not be sustainable. For cases of sustainable defection, the paper then investigates whether this defection is also *beneficial* for the cluster, i.e. if the fitness value obtained by clusters with egoistic agents is greater than the one found for the fully collective case.

3.1 Shock environments

In shock environments, the two benchmark scenarios of clusters with only defecting (Ego) or co-operating (Coll) agents perform relatively similar in adjustment (see columns 1 and 2 in Table 2). This suggests that the aforementioned advantages and shortcomings of co-operating and defecting agents (adjustment speed versus optimality and stability) are relatively similar in this situation. The performance of either local culture for the different groups however differs (see columns two and three in Table 3).[12] For instance group 2 obtains a fitness value of 0.7390 when cluster behaviour is under the egoistic regime in the medium interdependence case. Under the collective regime and the same conditions, the average fitness of group 2 is lower (0.7238). Similar aspects hold for the other agent groups in the cluster (results not reported here). A specific local culture may thus be optimal for the cluster but not necessarily for all agent groups (and vice versa).

Table 2 Adjustment to slow and fast shock environments: cluster fitness

Slow	Ego	Coll	Ego1	Ego2	Ego3	Ego4	Ego5
Low	0.7412	0.7389	0.7409	0.7410	0.7403	0.7401	0.7366
Medium	0.7321	0.7355	0.7342	0.7345	0.7319	0.7346	0.7252
High	0.7177	0.7177	0.7140	**0.7192**[a]	0.7160	0.7190	0.7152
Fast	**Ego**	**Coll**	**Ego1**	**Ego2**	**Ego3**	**Ego4**	**Ego5**
Low	0.7397	0.7384	0.7395	0.7395	0.7387	0.7386	0.7353
Medium	0.7289	0.7317	0.7308	0.7312	0.7287	0.7311	0.7223
High	0.7138	0.7137	0.7100	0.7150	0.7118	0.7144	0.7108

[a] Bold cases of sustainable and beneficial defection

Regarding the performance of clusters with a limited number of defecting agents, the model finds that egoistic behaviour by an entire group (Ego5) is never sustainable within a collective local culture. This constellation exhibits a pay-off structure similar to the prisoner's dilemma. If an entire group defects (here: group 1), its fitness value becomes maximal. The co-operating neighbour group (here: group 2), however, has a fitness value below that in the egoistic case (all defect). In such a situation, the collective local culture would be replaced by the egoistic one as there is only one dominant strategy for each group: Defection.

[12] For simplicity and space reasons, only the fitness values of groups 1 and 2 are reported here as they are decisive for determining whether defection pays and/ or is sustainable.

Table 3 Adjustment in slow and fast shock environments: group fitness

Slow	Gr.	Ego	Coll	Ego1	Ego2	Ego3	Ego4	Ego5
Low	1	0.7457	0.7388	0.7448	0.7509	0.7507	0.7485	0.7608
	2	0.7505	0.7512	0.7474	0.7414	0.7423	0.7442	0.7160
Med.	1	0.7390	0.7417	0.7344	0.7343	0.7351	0.7422	0.7635
	2	0.7306	0.7238	*0.7327*[a]	*0.7372*	0.7187	0.7219	0.6615
High	1	0.7105	0.7284	0.7094	0.7179	0.7073	0.7194	0.7748
	2	0.7225	0.7099	0.7206	**0.7247**[b]	*0.7257*	0.7173	0.6488
Fast	**Gr.**	**Ego**	**Coll**	**Ego1**	**Ego2**	**Ego3**	**Ego4**	**Ego5**
Low	1	0.7444	0.7373	0.7434	0.7494	0.7493	0.7468	0.7579
	2	0.7486	0.7496	0.7459	0.7397	0.7404	0.7424	0.7176
Med.	1	0.7358	0.7389	0.7313	0.7317	0.7321	0.7402	0.7540
	2	0.7272	0.7192	*0.7288*	*0.7333*	0.7149	0.7165	0.6670
High	1	0.7067	0.7239	0.7059	0.7145	0.7042	0.7166	0.7609
	2	0.7191	0.7055	0.7162	0.7129	*0.7197*	0.7094	0.6522

[a] Italics cases of sustainable defection
[b] Bold cases of sustainable and beneficial defection

The only cases in which defection can be sustainable within the collective local culture are those clusters in which the first group exhibits both co-operating and defecting agents. The existence of one or two egoistic agents is sustainable for clusters with medium interdependence, whereas a cluster characterised by high interdependence could host two or three defectors (see numbers in italics in Table 3). Results for an adjustment time of 300 steps after each total environmental change are identical, except for the fact that in high interdependence clusters, the first group can only hold three defectors. However, sustainable defection is almost never beneficial to cluster adjustment. There is only one case in which defection is both sustainable and beneficial: A cluster responding to slow shocks with high interdependence and two defecting agents in the first group (see number in bold in Table 2).

A final aspect worthy to note is the effect of defection on the fitness of the agent group from which defectors originate (group 1). As interdependence increases, defection pays less. In the low interdependence case, the average fitness of group 1 in case of Ego1-5 was always above the value obtained in the collective case, i.e. defection rather than collaboration benefited the group itself. In the medium and high interdependence scenario, this no longer holds for mixed agent groups (see fitness values of group 1 in Table 3). This stems from the fact that with growing interdependence, defecting agents in the first group tend to disturb those in the second one more strongly. As actors in the second group try to adjust to these interferences, their strategies may also have adverse repercussions on the first group. Defection thus pays less as interdependence in the cluster grows.

These results suggest that clusters in shock environments with low interdependence in production are unlikely to exhibit collective local cultures. Defection pays for the agent's group and is not sustainable within the local culture suggesting that one would witness a shift from the altruistic to the egoistic case. If interdependence is medium or high, however, collective local cultures are more stable. Although defection would hardly be sustainable or beneficial for the cluster, the incentives are low as it does not pay for the agent and her group to behave egoistically. Nonetheless, the benefits of having a collective local culture over an egoistic one are relatively small.

3.2 Disturbance environments

In contrast to the case of a total environmental change, the two benchmark cases of 'pure-strategy' clusters (Ego and Coll) perform very differently if change is only partial. Here, the collective case always excels and its lead increases with interdependence between cluster agents (see Tables 4 and 5). In line with proposition one, this suggests that the advantages of altruistic agents regarding stability and performance of adjustment are more important than the speed of finding new agent configurations. This aspect grows in importance (as suggested in Sect. 2.3) as the extent of interdependence between actors grows. While speed may matter for clusters facing very volatile environments, optimality is a greater concern in more stable conditions.

Similarly to the case of shocks, a cluster's local culture can be optimal for the cluster as a whole while not maximising the fitness value of all agent groups. Moreover, an entire group of egoists is not sustainable. However, mixed groups with egoistic and altruistic agents (Ego1-4) are all sustainable degrees of defection in the case of partial environmental change (i.e. the fitness level of the neighbour group 2 does not decrease below the egoistic case; see numbers in italics in Table 5).

An interesting aspect regards the comparison of cluster adjustment to partial environmental change for different adjustment times (600 versus 300 simulation steps). While this does not alter the results regarding sustainable defection, it has a significant impact on the number of cases in which defection is also beneficial (see numbers in bold in Table 4). Clusters facing a slow disturbance environment find sustainable and beneficial defection for the case of two egoists in a medium interdependence cluster. Clusters exposed to a fast disturbance environment find six cases of sustainable and beneficial defection. This increase in sustainable and beneficial defection shows that

Table 4 Adjustment in slow and fast disturbance environments: cluster fitness

Slow	Ego	Coll	Ego1	Ego2	Ego3	Ego4	Ego5
Low	0.7309	0.7431	0.7421	0.7412	0.7413	0.7414	0.7383
Medium	0.7234	0.7348	0.7284	**0.7368**[a]	0.7322	0.7334	0.7269
High	0.6999	0.7262	0.7258	0.7231	0.7218	0.7226	0.7222
Fast	**Ego**	**Coll**	**Ego1**	**Ego2**	**Ego3**	**Ego4**	**Ego5**
Low	0.7229	0.7329	**0.7331**	**0.7334**	**0.7344**	**0.7331**	0.7297
Medium	0.7178	0.7325	0.7292	0.7299	0.7300	**0.7333**	0.7244
High	0.6915	0.7249	0.7233	**0.7254**	0.7246	0.7242	0.7146

[a] Bold cases of sustainable and beneficial defection

Table 5 Adjustment in slow and fast disturbance environments: group fitness

Slow	Gr.	Ego	Coll	Ego1	Ego2	Ego3	Ego4	Ego5
Low	1	0.7327	0.7436	0.7411	0.7433	0.7485	0.7474	0.7610
	2	0.7227	0.7304	*0.7357*[a]	*0.7325*	*0.7286*	*0.7272*	0.7039
Med.	1	0.7441	0.7510	0.7354	0.7422	0.7447	0.7442	0.7827
	2	0.7013	0.7294	*0.7394*	**0.7339**[b]	*0.7096*	*0.7161*	0.6643
High	1	0.6902	0.7140	0.7378	0.7218	0.7205	0.7248	0.7811
	2	0.6996	0.7410	*0.7150*	*0.7202*	*0.7202*	*0.7169*	0.6484

Fast	Gr.	Ego	Coll	Ego1	Ego2	Ego3	Ego4	Ego5
Low	1	0.7236	0.7292	0.7397	0.7381	0.7358	0.7358	0.7509
	2	0.7259	0.7406	**0.7317**	**0.7333**	**0.7342**	**0.7338**	0.7055
Med.	1	0.7301	0.7469	0.7420	0.7499	0.7357	0.7411	0.7682
	2	0.7072	0.7278	0.7232	*0.7288*	*0.7318*	**0.7378**	0.6740
High	1	0.6925	0.7386	0.7266	0.7283	0.7304	0.7410	0.7720
	2	0.6901	0.7062	*0.7233*	**0.7290**	*0.7181*	*0.7063*	0.6552

[a] Italics cases of sustainable defection
[b] Bold cases of sustainable and beneficial defection

the speed advantages of egoistic agents materialise quite strongly in clusters with environments that change frequently but are more stable regarding the extent of change. Contrary to the case of total environmental change, the benefit of defection to the originating group (group 1) does not straightforwardly decrease with cluster interdependence (compare the fitness values of group 1 in Table 5 for the low and the high interdependence case). Defection therefore also pays for the originating group in cases of low of high interdependence within the cluster. Clusters facing disturbance environments would therefore tend to exhibit stable collective local cultures as these convey significant performance benefits. While defection pays, it is also sustainable and at times beneficial to adjustment - unless an entire group of producers in the cluster starts to behave egoistically.

The fact that defection is only sustainable in mixed agent groups brings about the question of its impact on group and cluster dynamics. As was highlighted in Sect. 2.1, agents in the cluster engage in a bidding process to have their configuration chosen to represent the group. This mechanism implies that the observation of and learning from competing firms in a cluster (represented by all agents in one group) leads to a diffusion of best practice. In clusters, this best practice corresponds to agent strategies that work well in the context of other's activities. As a result, the bidding process was based on expected cluster fitness, i.e. the agent proposing the best configuration for the cluster was chosen to represent her group. Agent behaviour (i.e. her adherence to or defection from the collective local culture) will thus only impact on the dynamics of her group and the cluster if she gets to be chosen in the bidding process.

The likelihood of being chosen however differs for egoistic and altruistic agents. As altruists choose strategies that are beneficial for the cluster, their selection mechanism is identical to the choice criterion of the bidding process. This decreases the likelihood that egoists come to determine group behaviour.[13] The likelihood of being chosen further decreases for egoistic agents if there are fewer of them (i.e. fewer 'egoistic' configurations being proposed) and if interdependence between agent groups increases (as defecting agents do not take this interdependence into account when proposing their configurations). In constellations where the remaining co-operating agent(s) in the first group dominate group behaviour, we find cluster dynamics that are very similar to the collective case (and that might exaggerate the extent of sustainable defection) - except for the fact that with fewer co-operating agents per group, adjustment would proceed more slowly as the number of agents searching 'collectively' declines.

To account for this aspect, the bidding process was changed to favour those configurations that led to the highest expected average fitness for the respective agent group.[14] This implies that agent and group selection criteria now favour strategies proposed by defectors, which would lead to a greater impact of defectors on group and cluster dynamics. The likelihood that defector strategies dominate the behaviour of the first group then increases with the number of defecting agents and decreases with the extent of inter-agent interdependence. This modification only leads to greater amounts of sustainable defection in the case of partial environmental change. However, this defection is *never* beneficial to the adjustment of the cluster as a whole (results not reported here).

4 Discussion

The present paper set out to investigate whether defection from a collective local culture can be sustainable in clusters and to what extent it may even benefit the cluster's adjustment to changing economic conditions as has been suggested in the literature. It finds that egoistic agents defecting from a collective local culture provide benefits regarding the speed of adjustment while altruistic ones complying with the established consensus allow for better and more stable adaptation. The advantages and shortcomings of both agent types map out differently depending on the nature of the cluster, the environment and the role of defectors for group behaviour.

Regarding the nature of the cluster, the extent of externalities between agents matters. In clusters characterised by high interdependence between agents (i.e. clusters with strong agglomeration externalities), compliance with a collective local culture is very beneficial. Altruistic agents gearing the selection of their strategies at the well-being of the entire cluster internalise the externalities of their activities into their strategy selection. While this optimisation of agent configurations tends to take longer, its results become superior, the greater the importance of the inter-agent externalities. As a consequence, clusters with very interdependent production processes will tend to have collective local cultures. Even if defecting agents are located in the cluster, they are relatively unlikely to come to dominate group behaviour as their selection

[13] An agent wanting to improve the expected average fitness of the $n = 6$ activities under her control is less likely to find configurations that increase the expected average fitness of the cluster. She would therefore have a smaller likelihood to be chosen as the group representative if there are agents in the group that already seek strategies improving the expected average fitness of the $N = 24$ activities making up the cluster.

[14] Such a setting could be imagined for clusters that do not only trade a final product but also intermediates.

mechanism performs very badly in comparison to that of altruists. It therefore seems as if agglomeration externalities (inter-agent interdependence) and a collective local culture are reciprocally interdependent: While the literature argues that a (collective) local culture is needed to establish agglomeration externalities, the findings presented here suggest that once established, agglomeration externalities support a collective local culture by reducing the payoff for defection.

As far as the nature of the environment is concerned, the extent and frequency of change acts as a main determinant. In very volatile environments (total environmental change), the advantages and downsides of altruistic and egoistic strategies (speed versus optimality and stability) are relatively equal. This notion is supported by the small differences in adjustment performance between the benchmark cases of collective and egoistic clusters. Moreover, defection in mixed strategy clusters is only sustainable in a limited number of cases and there is only one situation in which defection is both sustainable and beneficial to the cluster. This evidence would suggest that clusters facing extremely volatile economic conditions have are limited incentives to establishing a collective local culture as compared to adopting a 'Darwinist' attitude that allows every agent to act in her own best interest. This picture changes in the case of partial environmental change. Here, the benefits of altruistic agents regarding performance and stability of adjustment materialise more strongly. The speed advantage of egoistic agents only becomes important if the time to adjust to change is short. In sum, clusters in less volatile environments benefit very strongly from establishing a collective local culture as compared to the egoistic case. The strong benefits to altruistic agents in this setting then imply that defection may play a more limited role in the dynamics of agent groups and the cluster - provided that groups do not contain defecting agents alone.

Finally, the role of egoistic agents for group behaviour is key. This relates to the criterion for best practice in the cluster. In cases where best practice of an agent group is based on the highest expected cluster fitness, co-operating agents have a greater likelihood to dominate group behaviour as their individual selection mechanism corresponds to the choice criterion at the group level. This situation could be expected in clusters where all activities contribute to the manufacture of one final product. In cases where best practice in the group is based on highest expected average group fitness, the selection mechanism of defecting agents is closer to the group level one, thus giving defectors a greater likelihood of being chosen. This could be the case in clusters where not only the final product is traded beyond the cluster's boundaries but also the intermediate goods produced by each agent group. In the case of a bidding process based on agent group fitness, there tends to be less sustainable defection in volatile environments, suggesting that such clusters should tend to exhibit more egoistic local cultures.

These findings highlight a variety of issues that are usually left more implicit in the literature. Nonetheless, several limitations remain. First, the model gives an admittedly rough account of the microdynamics underlying co-operation and defection in clusters. By aggregating agent dynamics into a single group configuration in every simulation step, a number of aspects at the agent level (such as individual fitness) are lost. Second, by measuring average fitness over 300 or 600 simulation steps and aggregating these over 100 simulations, we obtain results for the effects of defection in a majority of cases. In other words, the model describes the extent of defection that is sustainable and/or beneficial to the cluster in most cases whereas there may be simulations in which more or less defection pays. Third, in order to isolate the effect of defection on cluster performance, the model treats the extent of agglomeration externalities (interdependence) as given. When following the argument of the existing literature, however, the extent of agglomeration externalities could be expected to change with defection of cluster agents: If defectors are excluded from all future network exchanges, this will have repercussions on agent interdependence in the cluster. Since the degree of interdependence is an important determinant of N/K system dynamics, this aspect was left unaccounted for to avoid that results would be driven by other forces than the one under study here. Finally, the model currently does not have emergence or selection dynamics at the level of cluster agents. In real-world clusters, it could however be imagined that the effects of defection on other agents might be so severe, that these actors are no longer competitive and have to leave the market. This would then have repercussions on the performance of remaining agents and the cluster.

While these limitations imply that the model results should be read as tendencies rather than deterministic predictions, the findings do indicate that defection pays less in clusters than could have been expected. As a result, a collective local culture can be more stable than is usually acknowledged. Moreover, the model highlights that defection in the cluster is only likely to come to impact on group and cluster dynamics, if defectors discover strategies that are superior to those found by agents adhering to the local culture. To determine in greater detail how the microdynamics of co-operation and defection map out in clusters, substantial further theoretic and empirical research will however be needed.

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