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DIVIDE AND CONQUER? THE ROLE OF GOVERNANCE FOR THE ADAPTABILITY OF INDUSTRIAL DISTRICTS

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This paper develops a simulation model of the behavior of industrial districts in the face of changes in their environment. By applying Kauffman's N/K-C model to the question of optimum governance in industrial districts facing an external shock, the paper sheds light on the optimum co-ordination mechanism among agents in interdependent industrial networks. Simulation results indicate that collective governance structures with agents adjusting for the sake of the district as a whole perform best in adaptation, whereas individualistic governance modes deliver the worst results. Alliance and leader firm governance forms position themselves in-between these two extremes. However, both modes of governance can be preferable to the collective one if the observation and punishment mechanisms in the district's local culture are not strong enough to impose solidarity among its agents. In this case, a prisoner's dilemma emerges and the collective governance form is replaced by the inferior individualistic one. Through these results, the model highlights the link between governance and district adaptability. It provides an explanation for the trend in Italian districts towards more hierarchical governance structures. Moreover, the identification of the role played by governance structure for district adaptability in changing environments could serve as guidance for future research.

Keywords: Industrial districts; adaptation; N/K model.

1. Introduction

The phenomenon of non-random spatial concentrations of firms in one or a few related sectors — often referred to as clusters [13, 14] — has become a hot topic in both economic theory and policy. Based on ideas first advanced in Alfred Marshall's *Principles of Economics* (1890), their existence is justified by the permanent advantages accruing to co-located firms. The latter stem from agglomeration economies, which state that the co-location of many firms in an area leads to positive externalities between their activities, including (Ref. 34, p. 271):

(i) information spillovers due to inter-firm observation and collaboration;
(ii) pooled labor markets due to immigration and local firms' training activities;
(iii) scale and specialization benefits due to a division of labor.

Agglomeration economies thus contribute to and create an interdependence between (the success of) firm activities. As a result, they lead to a greater spatial embeddedness of agents: if being local is the key to accessing the benefits resulting from agglomeration economies, firms will be less willing to leave the area than they would be according to cost considerations alone [21, 41]. It is this generation of spatial inertia that has led to the increased interest in clusters by researchers in economic theory and policy. In some instances, clusters are viewed as an opposing force to globalization, helping regions create or retain prosperity.

What is often forgotten in the euphoria about the benefits of successful clusters to their host regions is the fact that areas facing severe structural problems today (such as the old industrial centers of the Ruhr in Germany or Detroit in the US) were thriving clusters in the heyday of their industries. However, as the technological evolution progressed, agents in these clusters proved unable to adapt and were rendered obsolete. Put differently, "*what once was a leading centre of dynamism within a given line of business [can end] up as an 'old industrial region', facing great problems of renewal and finding itself out-competed by firms located elsewhere*" (Ref. 31, p. 432). A decline of clusters is often brought about by external developments that impact on the cluster like an outside *shock*. Such shocks can originate with changes in technology, the nature of market demand or host country legislation.

The relationship between clusters and their host area is thus a Janus-faced phenomenon. In times of prosperity, clusters convey considerable benefits to the greater region, whereas their decline can have severe long-term repercussions for local economic development. This second issue of cluster decline is now being increasingly addressed in the literature, especially in the context of Italian industrial districts (henceforth: districts[a]). These districts constitute a special version of clusters composed of (mainly) small and medium sized enterprises (SMEs) that specialize in different stages of the value chain and produce a final product in flexible networks of suppliers and end-producers [37]. Case studies have identified a role of governance in enhancing district adaptability to external shocks after observing that in the course of district adaptation, governance repeatedly shifted away from egalitarian networks towards an increased hierarchisation. This development has primarily involved the emergence of *leader firms* through a concentration of power; or the creation of *alliances* where several independent district firms joined forces in more closely linked business groups (see Refs. 3, 6, 8, 19, 28, 30, 45).

The present paper seeks to address the causalities underlying this case-study derived trend towards hierarchical governance structures by investigating the link between governance and district survival using a general theoretic model. This model will show how and when governance can assist district adaptability to external shocks and thereby survival since "*It is not the strongest of the species that survive, nor the most intelligent, but the one most responsive to change*" [11]. In

[a]See among many others Refs. 1, 2, 4, 36, 42 and 46.

doing so, the model provides one possible explanation for the observed empirical trends and generates causal links that may act as guidance to future case studies. While the results derived in this paper are based on findings in the industrial district literature, the generality of the model also makes them applicable to other types of clusters.

2. The Model

In order to shed light on the link between governance structure and district adaptability, a model must include the following three components: different types of district governance, external shocks and adaptation. The following sections provide additional detail on each of these points. Generally speaking, the link between governance and adaptability is addressed by modeling districts as complex systems based on Kauffman's N/K model. Starting with the known properties of N/K systems (see Refs. 12, 15, 18, 32, 33, 40 and references therein), the model argues that governance influences district adaptability by gearing agent selection processes towards better or worse results for the district as a whole. This proposition on the role of governance for adaptability is then tested by simulations.

2.1. *The nature of industrial districts*

Italian industrial districts are areas with "*geographically concentrated small and medium sized firms targeting their products at the upper market segment where they possess a competitive advantage regarding their flexibility and specialisation. This advantage is obtained through decentralised production in specialist firms with vertical cooperation and horizontal competition. A supportive social environment enables this mode of production and sustains it against economic crisis*" (Ref. 38, pp. 2–3). As can be derived from this definition, districts are composed of a variety of organizations (henceforth: agents) conducting activities in the local value chain. Their most elementary unit of analysis would be the activities dedicated to the manufacture of a (set of) marketable product(s). Due to a division of labor in districts, these local value chain activities do not reside within the control of one organization alone but are distributed among multiple agents. As a result, districts exhibit a horizontal dimension of firms with similar capabilities and competing activities as well as a vertical one where firm capabilities and activities are complementary (Ref. 35, pp. 927–928).

In the Marshallian perspective advanced in much of the literature, the nature of districts implies that their agents act under architectural constraints. These constraints stem from the existence of agglomeration externalities and a governance structure at the level of the district itself. Agglomeration externalities create interdependence between district agents in the sense that the success of any agent's activities not only hinges on her own strategy choices but also on the actions of others. For these externalities to emerge, however, a governance structure is required, i.e. a "*context of relations of power and structures of decision-making*" (Ref. 45,

p. 411). District governance forms act as a means to co-ordinate agent activities for good collective results by restricting free-riding and other forms of opportunistic behavior that would otherwise undermine the emergence of agglomeration externalities. They can take the form of a supportive social environment with informal rules of the game or that of authority relations between different district agents (for further details see Sec. 3.3). In the context of such a governance form, not all conceivable activities may then be available to an agent in the district. This can be the case if agent activities breach with established rules of the game, or if they cause conflict with a more powerful actor.

Agglomeration externalities and their supporting governance form are argued to increase the competitiveness of the district and its agents as compared to isolated organizations with the same characteristics. The overall success of any given district is then also determined by its greater environment, i.e. by characteristics of the host area, the district's industry as well as technological and market dynamics. Changes in any of these environmental aspects can act like a shock impacting upon a district with a given architecture (externalities, governance) that has evolved throughout its past history. The immediate adaptation of district agents to such a shock then has to proceed within the district architecture.

This nature of districts as agent-based systems with emergent district-level properties (externalities, governance) and environmental embeddedness means that they can be modeled as complex systems using Kauffman's N/K model [25]. Here, the elements (N) of the "system" district are the activities dedicated to the manufacture of a final product. Each of these elements can take on two states [0; 1], which reflect agent strategy choices for an activity. As a result, there are 2^N different system (district) configurations in total. An element's state then contributes to the *fitness* (the likelihood of survival) of the entire system (Ref. 25, p. 33), which equals the mean value of element fitness values. The fitness contribution of an individual element state (w_n) in turn represents the effectiveness of an agent's strategy choice with respect to one activity. It is drawn randomly from a uniform distribution between 0 and 1. In an N/K system, this fitness value can furthermore be *conditional* on the states of a number of other elements. The N/K framework thus allows for interdependence between the fitness values of element states. The character of this interdependence then depends on the kind of system analyzed.

In integrated systems where all elements are controlled by one agent, interdependence can occur only at the level of this agent (e.g. Refs. 16, 17 or 39). It is measured by the parameter K. In the case of disintegrated, co-evolving systems, elements are controlled by different agents and interdependence can therefore also exist between agents. This second type of interdependence is measured by the parameter C. In both cases, the values of K and C indicate the average number of other elements influencing the fitness contribution of any system element. If $K = 3$, the fitness of each system element (on average) depends on the states of three other elements within the control of the same agent. If $C = 3$, the fitness of each system element (on average) depends on three other elements that are controlled by other agents.

	Agent 1		Agent 2
	1	2	3
w_1	—	x	
w_2	x	—	
w_3			—

	Agent 1		Agent 2
	1	2	3
w_1	—		
w_2	x	—	***x***
w_3			—

Fig. 1. K and C externalities in an $N = 3$ element system.

The difference between the two externalities is illustrated in Fig. 1. On the left-hand side, the outcomes of activities one and two are mutually interdependent, i.e. the fitness value of n_1 (w_1) depends on the state of n_2, and *vice versa*. Since they are both controlled by agent 1, the interdependence (x) in this system is at the level of agents alone (K). Agent 1 could therefore align his strategy choices with respect to a combination of states for n_1 and n_2 that maximizes his overall fitness. In the system depicted on the right-hand side of Fig. 1, elements one and two as well as elements two and three are interdependent. The fitness contribution of n_2 (w_2) thus depends on the state of element n_1 and that of element n_3. While agent 1 can still align the states of elements n_1 and n_2, his maximum fitness will only be attained if agent 2 makes a suitable choice for the state of n_3. In this kind of system, interdependence therefore exists at the level of agents (x) and between agents ($\boldsymbol{x}$). The existence of inter-agent interdependence (C) then implies that individual strategies may not lead to collectively optimal results.

Due to the local division of labor, districts fall into this second class of co-evolving systems. The N activities in the local value chain are allocated to different organizations, implying that interdependence can reside at the level of agents and between agents. The extent of cross-agent externalities (C) then represents the effects of agglomeration externalities. This notion of externalities includes both positive and negative effects from agglomeration. Positive externalities between activities in the N/K model would be present if, thanks to an interdependence between n_1 and n_3, the joint fitness contribution for a specific combination of element states $w(n_1 = 0 \cap n_2 = 0)$ exceeded the sum of fitness contributions for those two element states in independent systems, i.e. if $w(n_1 = 0 \cap n_2 = 0) > w(n_1 = 0) + w(n_2 = 0)$. The opposite holds for negative feedback effects. The parameter C captures both types of interdependencies, thus encompassing both positive and negative externalities between firm activities in co-location. This extends beyond the traditional Marshallian agglomeration economies to include diseconomies from agglomeration as well. While empirical studies do find negative effects of co-location (e.g. Ref. 43), the theoretic literature mainly emphasizes positive externalities. The results generated by this model can nonetheless be used to address the existing literature. While the nature of externalities matters for the absolute fitness values of district configurations (and thereby for absolute district performance in adaptation), they are kept identical for all districts modeled here. As a result, their exact nature is not important for determining the *relative* performance of different governance structures, which is the goal of the present paper.

Taking all possible element states and the influence of interdependencies into account allows for a mapping of all 2^N possible system configurations and their respective fitness in *fitness landscapes*. Within a given environmental setting, any district configuration has a certain fitness, which acts as a criterion of the success of its current way of doing business. This district configuration is derived from the activities of its agents (choice of element states) and the influence of interdependencies. In the model developed here, element interdependence was determined by adopting a block-diagonal distribution with different block lengths. Moreover, a setup was chosen in which the district contained $N = 24$ value chain activities that were evenly distributed between four different groups of agents. Depending on the extent to which interdependencies occurred between elements under the control of one agent or between agents, the parameter values of K and C were derived by dividing the total number of intra- (x) and inter-agent externalities ($\boldsymbol{x}$) by the number of elements ($N = 24$). Figure 2 illustrates this for two example cases of $C = 0.67$ and $C = 6$.

Due to the division of labor in districts, the activities in each stage of the value chain do not reside within the control of one organization alone but are conducted by groups of several agents. The basic model set-up used in this paper is described in Fig. 3. It involves an industrial district with $N = 24$ value chain activities. Each of the four groups representing one stage of production consists of five organizations that all conduct the same range of $n = 6$ activities. Agents in group 1 thus conduct competing activities and represent the horizontal dimension of the district whereas the activities of agents in groups 1–4 (vertical dimension) are complementary.[b]

2.2. *External shocks and adaptation*

As was highlighted in the introductory section, external developments can act as a *shock* to a district if they reduce the success (the fitness) of its current configuration. In the case of Italian districts, these shocks often derived from competitive pressures. Firms in developing countries increasingly targeted some of the traditional markets of Italian districts (clothing or shoes) and new production technologies enabled large multinational firms to match their capacities in product customization — in many cases at a lower price [see Refs. 1, 2, 4, 36, 42 and references therein]. While many districts remained successful in customizing products, this previous core competence became somewhat more ubiquitous, thereby reducing district fitness. In the N/K model developed in this paper, external shocks were

[b]In its current implementation, the model only includes externalities in the vertical dimension of the district. While it is reasonable to assume that agglomeration externalities emerge at the horizontal and vertical level of districts, their indirect and often time-lagged effect makes it difficult to allocate them to either dimension. Following Ref. 35, it is argued that the main externality associated with the horizontal level is that of a learning from observation of and comparison with competitors. It will be reflected in the dynamics of agent groups in the present model (Sec. 2.2).

	GROUP 1						GROUP 2						GROUP 3						GROUP 4					
	n_1	n_2	n_3	n_4	n_5	n_6	n_7	n_8	n_9	n_{10}	n_{11}	n_{12}	n_{13}	n_{14}	n_{15}	n_{16}	n_{17}	n_{18}	n_{19}	n_{20}	n_{21}	n_{22}	n_{23}	n_{24}
w_1	-	x	x	x																				
w_2	x	-	x	x																				
w_3	x	x	-	x																		C=0.67		
w_4	x	x	x	-																				
w_5					-	x	**x**	**x**																
w_6					x	-	**x**	**x**																
w_7					**x**	**x**	-	x																
w_8					**x**	**x**	x	-																
w_9									-	x	x	x												
w_{10}									x	-	x	x												
w_{11}									x	x	-	x												
w_{12}									x	x	x	-												
w_{13}													-	x	x	x								
w_{14}													x	-	x	x								
w_{15}													x	x	-	x								
w_{16}													x	x	x	-								
w_{17}																	-	x	**x**	**x**				
w_{18}																	x	-	**x**	**x**				
w_{19}																	**x**	**x**	-	x				
w_{20}																	**x**	**x**	x	-				
w_{21}																					-	x	x	x
w_{22}																					x	-	x	x
w_{23}																					x	x	-	x
w_{24}																					x	x	x	-

	GROUP 1						GROUP 2						GROUP 3						GROUP 4					
	n_1	n_2	n_3	n_4	n_5	n_6	n_7	n_8	n_9	n_{10}	n_{11}	n_{12}	n_{13}	n_{14}	n_{15}	n_{16}	n_{17}	n_{18}	n_{19}	n_{20}	n_{21}	n_{22}	n_{23}	n_{24}
w_1	-	x	x	x	x	x	**x**	**x**	**x**	**x**	**x**	**x**												
w_2	x	-	x	x	x	x	**x**	**x**	**x**	**x**	**x**	**x**												
w_3	x	x	-	x	x	x	**x**	**x**	**x**	**x**	**x**	**x**										C=6.00		
w_4	x	x	x	-	x	x	**x**	**x**	**x**	**x**	**x**	**x**												
w_5	x	x	x	x	-	x	**x**	**x**	**x**	**x**	**x**	**x**												
w_6	x	x	x	x	x	-	**x**	**x**	**x**	**x**	**x**	**x**												
w_7	**x**	**x**	**x**	**x**	**x**	**x**	-	x	x	x	x	x												
w_8	**x**	**x**	**x**	**x**	**x**	**x**	x	-	x	x	x	x												
w_9	**x**	**x**	**x**	**x**	**x**	**x**	x	x	-	x	x	x												
w_{10}	**x**	**x**	**x**	**x**	**x**	**x**	x	x	x	-	x	x												
w_{11}	**x**	**x**	**x**	**x**	**x**	**x**	x	x	x	x	-	x												
w_{12}	**x**	**x**	**x**	**x**	**x**	**x**	x	x	x	x	x	-												
w_{13}													-	x	x	x	x	x	**x**	**x**	**x**	**x**	**x**	**x**
w_{14}													x	-	x	x	x	x	**x**	**x**	**x**	**x**	**x**	**x**
w_{15}													x	x	-	x	x	x	**x**	**x**	**x**	**x**	**x**	**x**
w_{16}													x	x	x	-	x	x	**x**	**x**	**x**	**x**	**x**	**x**
w_{17}													x	x	x	x	-	x	**x**	**x**	**x**	**x**	**x**	**x**
w_{18}													x	x	x	x	x	-	**x**	**x**	**x**	**x**	**x**	**x**
w_{19}													**x**	**x**	**x**	**x**	**x**	**x**	-	x	x	x	x	x
w_{20}													**x**	**x**	**x**	**x**	**x**	**x**	x	-	x	x	x	x
w_{21}													**x**	**x**	**x**	**x**	**x**	**x**	x	x	-	x	x	x
w_{22}													**x**	**x**	**x**	**x**	**x**	**x**	x	x	x	-	x	x
w_{23}													**x**	**x**	**x**	**x**	**x**	**x**	x	x	x	x	-	x
w_{24}													**x**	**x**	**x**	**x**	**x**	**x**	x	x	x	x	x	-

Fig. 2. Fitness landscape structures.

	AGENTS IN GROUP1						AGENTS IN GROUP2						AGENTS IN GROUP3						AGENTS IN GROUP4					
1	n_1	n_2	n_3	n_4	n_5	n_6	n_7	n_8	n_9	n_{10}	n_{11}	n_{12}	n_{13}	n_{14}	n_{15}	n_{16}	n_{17}	n_{18}	n_{19}	n_{20}	n_{21}	n_{22}	n_{23}	n_{24}
2	n_1	n_2	n_3	n_4	n_5	n_6	n_7	n_8	n_9	n_{10}	n_{11}	n_{12}	n_{13}	n_{14}	n_{15}	n_{16}	n_{17}	n_{18}	n_{19}	n_{20}	n_{21}	n_{22}	n_{23}	n_{24}
3	n_1	n_2	n_3	n_4	n_5	n_6	n_7	n_8	n_9	n_{10}	n_{11}	n_{12}	n_{13}	n_{14}	n_{15}	n_{16}	n_{17}	n_{18}	n_{19}	n_{20}	n_{21}	n_{22}	n_{23}	n_{24}
4	n_1	n_2	n_3	n_4	n_5	n_6	n_7	n_8	n_9	n_{10}	n_{11}	n_{12}	n_{13}	n_{14}	n_{15}	n_{16}	n_{17}	n_{18}	n_{19}	n_{20}	n_{21}	n_{22}	n_{23}	n_{24}
5	n_1	n_2	n_3	n_4	n_5	n_6	n_7	n_8	n_9	n_{10}	n_{11}	n_{12}	n_{13}	n_{14}	n_{15}	n_{16}	n_{17}	n_{18}	n_{19}	n_{20}	n_{21}	n_{22}	n_{23}	n_{24}

Fig. 3. Agents, groups and activities.

therefore introduced by changing the fitness contribution of all N elements while leaving the structure of interdependencies intact (akin to Ref. 26).

District adaptation to such shocks then involves having the agents in each group change the system by modifying the states of the activities under their control in search of better configurations. In the model, this process is developed as follows. In each simulation step, all district agents first *search* their fitness landscape subset for better strategies, i.e. agents modify the states of those elements (activities) that they conduct and thus control with a probability of 0.5. On average, they thus change three out of their six elements. For instance, one of the five agents in group 1 could change the configuration of elements $\{n_1 - n_6\}$ from $\{0; 0; 0; 0; 0; 0\}$ to $\{1; 0; 1; 0; 0; 1\}$.

Agents then *test* the new configuration of their six elements and *select* it if it constitutes a fitness improvement according to their selection criterion. This test and selection is based on the *expected* fitness of the new configuration, i.e. its fitness holding the states of the remaining 18 elements (out of 24) that are outside the agent's control constant. In a sense, agent search and selection activity is therefore *myopic*. Two aspects about districts speak in favor of this perspective. The first regards the notion of bounded rationality of district agents with respect to the exact mechanisms underlying agglomeration externalities. In other words, firms might not know that their good innovative performance partly relies on knowledge spillovers provided by collaborators. Second, even if actors do know that they depend on the activities of others, it is highly unlikely that any individual agent can foresee the exact effect of her individual choice as that would require being informed about the plans and future strategy choices of all other agents. Choosing a strategy that will work well in the current context is therefore an actor's best bet. As the very context changes with agent activities, individual actions may miss their goals or lead to unanticipated aggregate effects.

To get from the suggestions of modifications at the level of agents to the configuration of agent groups [see (1) in Fig. 4], a bidding process is introduced that selects the agent with the best configuration regarding the *expected* fitness of the district. This bidding process represents the learning from observation that is prominent at the horizontal level of districts, i.e. within each agent group (see also Ref. 35). A strong learning from observation would lead to a selection and imitation of best practice. In the case of districts where the success of firm activities depends on those of others, this would correspond to strategies that work well in the context of other agent (group) activities. To approximate this aspect, the bidding process is based on expected district fitness. These agent and group dynamics are executed

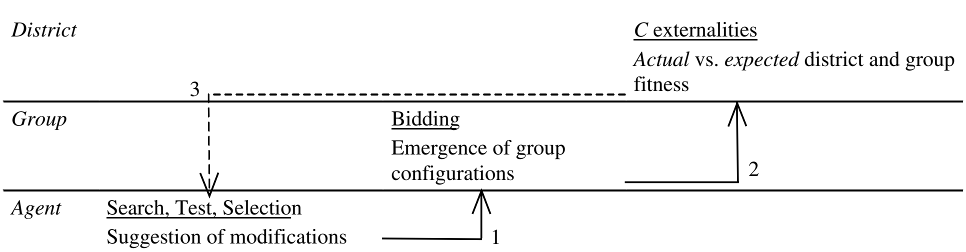

Fig. 4. The model in schematic representation.

simultaneously, thereby leading to the emergence of new configurations for groups 1–4. Taking all group configurations together and allowing for the cross-agent externalities to take hold [see (2) in Fig. 4] then gives the actual fitness values for the district and its agent groups. The next simulation step then starts with this new district and agent group configuration [see (3) in Fig. 4].

The adaptability of districts in this model relates to how well individual strategies and district architecture work together to allow for improvement in the district's configuration. District architecture influences agent and group dynamics in two ways. First, it determines the extent of cross-agent externalities (C), i.e. the degree to which the effectiveness of any change in agent strategy hinges on the activities of agents in other groups. Second, it can be argued that district governance will impact on the selection mechanism of agents since governance acts as a behavioral restraint. To single out the influence of governance on district adaptability, the model adopts an all-else-held-equal perspective, i.e. all districts in the model are identical except for their governance structure.

The aspect of governance is then incorporated by modeling districts with different selection criteria at the level of their agents. The argument underlying this notion is that depending on the relations of power in a district, agents will have different degrees of freedom to choose strategies: Agents in districts with a dominant firm would face punishment when selecting strategies that harm the key actor. Their motives for changing strategy will therefore focus on avoiding conflict with the dominant firm. This situation is likely to differ when agents are located in equal-power districts. As a result, governance impacts on one of the key determinants of N/K system behavior, namely *selection*. It therefore also influences district adaptability when modeled in this way. To allow for a comparison of relative adaptability of district governance modes, the other determinants of their behavior[c] are kept identical.

2.3. *Governance structure and adaptability*

For the Marshallian externalities that characterize industrial districts to emerge, a certain degree of governance is required. When faced with the decision to engage in activities enabling agglomeration externalities, individual agents often confront a prisoner's dilemma situation. Trained personnel, for instance cannot be bound to one employer forever, thus opening up an avenue for individual firms to free ride on others' training investment by hiring trained workers without contributing to the pooled labor market themselves. At the same time, specialization and division of labor will only occur if suppliers can be certain that they can sell their products at a fair price: "*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*

[c]These relate to the structure (extent and nature of interdependence, i.e. K and C values) as well as agent search mechanism and group dynamics in the district.

producing pin heads in vain." (Ref. 27, Book II, Ch. XII, p. 7). In order to capitalize on the advantages from agglomeration externalities, industrial districts are thus in need of a *governance structure* to limit undesirable behavior. This also implies that not all conceivable individual activities are possible within the context of a given district governance.

Two basic forms of governance have been discussed in the context of districts [45]: one with symmetrical power between district firms and one where power is asymmetrical, i.e. where there is a hierarchy between agents. In the first case (absence of hierarchy), the literature argues that governance is obtained through a set of localized formal and informal institutions that are often dubbed the *local culture*. The local culture regulates what constitutes acceptable business behavior in the area. Adherence to these rules of the game is sustained by collective observation and punishment mechanisms [20, 24]. Due to proximity, local actors are better informed about each other's activities than they would be when dealing with more distant parties (e.g. because agents interact beyond the business sphere alone [7, 10, 29]). As a result, "*it will be immediately noticed if a firm [in a district] attempts to [...] benefit at the expense of others [...]. Information about such misbehavior will be passed on to everyone, who in the future will tend to take their business elsewhere. Worse still, by becoming a local outcast, the firm is deprived of [other exchanges with cluster parties*[d]*], which can prove very difficult to substitute*" (Ref. 35, p. 926). If power in the district is distributed asymmetrically (i.e. in the case of hierarchy), agents with superior influence can use their prominent position in the district to mend the local rules of the game to their benefit. The threat of punishment by more powerful actors would then act as a mechanism sustaining adherence to the rules of the game in districts with hierarchical governance.

The aspect of governance is incorporated into the model by introducing different selection criteria for district agents that are conditional upon the present governance structure. Broadly, governance forms fall into four ideal-typical regimes:

(i) *Individualistic*: Agents seek to maximize their own fitness, i.e. that of the elements under their control.
(ii) *Collective*: Agents want to increase the fitness of the entire district.
(iii) *Alliance*: Agents seek to improve the joint fitness of themselves and their ally.
(iv) *Dominant (leader) firm*: Agents aim at bettering their own and the dominant firm's fitness while the latter behaves individualistically.

Cases (i) and (ii) represent districts with an even distribution of power but differing local cultures. Within any local culture, multiple rules regarding what constitutes acceptable business practice are possible. The extreme cases would be *individualistic* local cultures where local attitudes favor a Darwinist approach allowing all agents to act in their own best interest alone, and *collective* local cultures, where agents'

[d] For examples of the multiple coexisting inter-firm exchanges in districts, see Ref. 9.

activities are oriented to the well being of the district as a whole. In the first scenario (*individualistic*), district agents care about their own fitness when selecting a new strategy. Adaptation in the second type of district (*collective*) is geared at better district fitness. Put differently, agents in individualistic districts select any strategy that improves the expected average fitness of those six elements that they control. Agents in collective districts only select modifications in their strategies if the new configuration improves the expected average fitness of the $N = 24$ elements constituting the district.

In the two hierarchy settings (alliance, leader firm) that have come into prominence in Italian districts, acceptable business practice is likely to be different. A *leader firm* will probably "*influence the internal operations of other firms or units [...] in a systematic way*" (Ref. 45, p. 413) since none of the subordinate firms would have an interest in executing activities that could result in conflicts with the dominant actor of the district. The case of a *leader firm* modeled here thus asserts that group 1 has been replaced by one agent that dominates the district. As a consequence, all other agents seek to improve the expected average fitness of the leader firm and themselves while the leader firm behaves egoistically, seeking to maximize its individual fitness.[e] In the case of *alliances*, the local actors allied with one another would put the improvement of their joint situation over the well-being of non-alliance agents. In *alliance* districts, allies in groups $1+2$ and $3+4$ therefore try to increase their joint fitness, i.e. they select any configuration that improves the expected average fitness of elements n_1–n_{12} (groups $1 + 2$) or n_{13}–n_{24} (groups $3 + 4$).

The effect of selection (governance) for district adaptability will then depend on the number and system-level optimality of agent modifications generated under a specific selection rule. In co-evolving systems where changes in agent strategy can have repercussions for other agents (through C externalities), fewer modifications at the agent level increase the stability of adaptation. Moreover, the degree to which cross-agent externalities are internalized in agent decision-making determines the system-level optimality of modifications. The greater the internalization of C externalities (i.e. the more "collective" agent orientations) the better and the more stable adaptation: first, agents attempting at improving the fitness of a larger part of the system through search in their subset are less likely to encounter better modifications, i.e. they generate fewer changes in their configuration. At the same time, modifications found by agents with more collective mindsets will be better from the system's perspective. These aspects materialize to a different extent depending on the structure of the fitness landscape, i.e. regarding the existence and importance of C externalities between agents. If there are C externalities between actors, agents

[e]Agents in group 2 thus aim at increasing the fitness of elements n_1–n_6 and n_7–n_{12}, actors in group 3 aim at higher average fitness of elements n_1–n_6 and n_{13}–n_{18} while agents in group 4 seek to improve the fitness of elements n_1–n_6 and n_{19}–n_{24}. The dominant firm in group 1 in turn selects any configuration that increases the fitness of its own elements (n_1–n_6).

taking these into account when modifying their strategies will fare better than those acting individualistically, especially as the role of externalities increases.

3. Results and Discussion

All simulations were run using the LSD (Laboratory of Simulation Development) platform[f] for districts containing $N = 24$ elements with increasing levels of fitness landscape interdependence (higher C values). In order to avoid effects of one-off "lucky" adaptations, 100 simulations with different fitness landscapes were conducted for each parameter. This corresponds to a district adapting to 100 external shocks. The simulations were run for 600 steps. Average fitness and standard deviation were gathered both at the system, i.e. district, and at the (firm) group level, over the course of each simulation run. The results reported here correspond to the averages for both measures over all 100 runs.

Comparing performance (average fitness) and stability of adaptation (average standard deviation of fitness values) for different district governance structures yields a set of results. First, the simulations show that *district adaptability decreases with interdependence. The average fitness obtained in adaptation decreases and the fluctuations in the adjustment process rise.* This is hardly surprising considering that a greater number of interdependencies between agent activities makes it harder to optimize (parts) of the system: changing one element has repercussions on the fitness values of many other elements. However, the losses of system fitness differ between the governance structures modeled. For small values of C, all selection mechanisms perform relatively similarly, but beyond a critical value, a gap begins to open up, with the *collective* district performing best, losing only 9.59% of its fitness between the simplest and the most interdependent fitness landscape. The *individualistic* scenario performs worst and loses almost one third (29.55%) of its fitness. Both *leader* and *alliance* districts position themselves between these two extremes, losing about 20% of fitness as C becomes maximal. This observation highlights that *governance structure begins to matter more as the role of cross-agent externalities increases.*

In line with the expectation advanced in the previous section, the collective district exhibits the most stable adaptation processes with best results (Fig. 5) whereas the individualistic district begins faring worst once inter-agent externalities pass a threshold value ($C = 4.04$). Alliance and leader firm governance structures yield intermediate results. Their relative performance becomes more similar as inter-agent externalities increase.

[f]The LSD platform developed by Marco Valente (see http://www.business.aau.dk/∼mv/Lsd/lsd.html) is a freely available shareware program covering a wide range of economic simulation models. Interested uses can find the program and example models online. All code and results of the model presented here are available from the author.

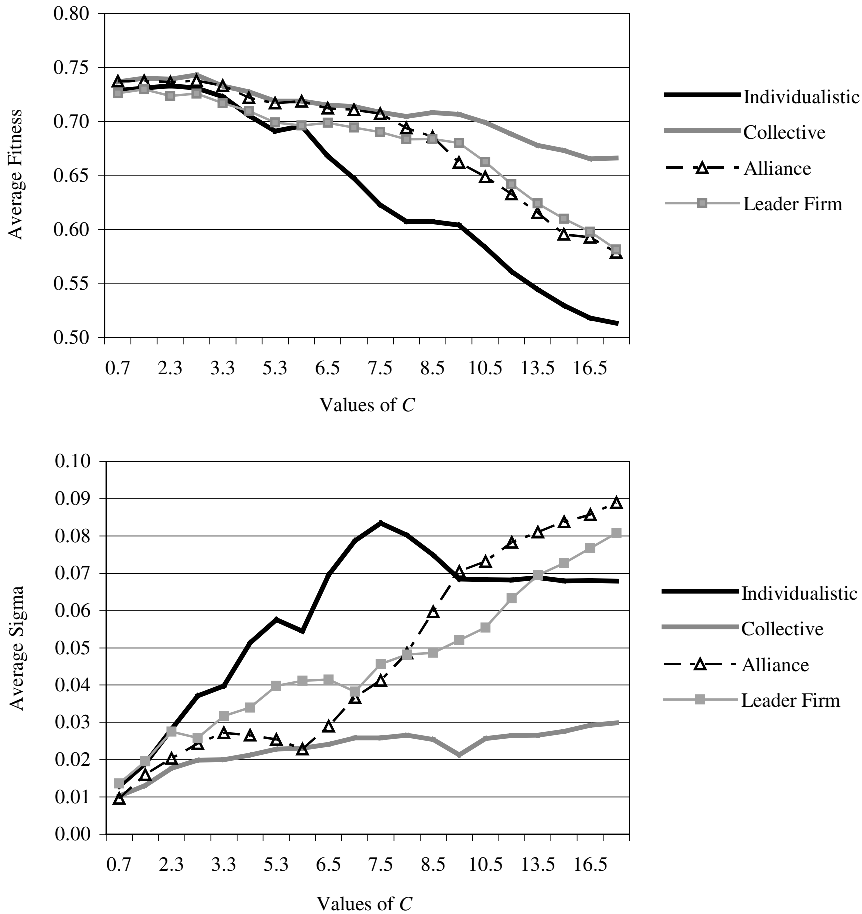

Fig. 5. Governance structure and district adaptability (averages over 100 simulation runs).

Having seen that the collective case is the best obtainable governance form from the district's perspective, one may ask why Italian districts are instead moving towards hierarchical structures. Three possible rationales exist for this phenomenon. First of all, governance structures need not be optimal. Firms might have come to dominate the district or have formed alliances for a variety of reasons within a period of stability. If a shock then hits the district, it is "stuck" with its governance structure and its consequences for adaptive performance. In a way, such a perspective would turn causalities around: governance structures form for other reasons and then have an impact on the adaptability of the district in the face of environmental shocks. However, even within the context of the model developed here, some notions can be advanced in favor of alliance and leader firm constellations as compared to the collective case. These aspects include the speed of adjustment, the group-level optimality of governance structures, and the strength of their underlying enforcement mechanism.

Previous studies applying the N/K model to the case of organizational adaptation [12, 32, 33] have noted that agents targeting their search and modification at the optimization of the entire system are bound to take longer than actors involved with decentralized search geared at optimizing system parts. This is attributable to the larger problem space, i.e. it takes longer to find a better element configuration in a problem space of $N = 24$ with two possible states for each element (equaling 2^{24} possibilities) than in one with $N = 6$ (2^6) or $N = 12$ (2^{12}). Alliance or leader firm scenarios can therefore be preferable to collective governance as they enable agents to discover improvements in their system subset more quickly. Future work reducing the number of simulation steps allowed for agent adjustment will however be required to assess the effect of speed on district adaptability.

Another possible explanation for the trend towards hierarchy-based governance forms lies with their optimality at different levels of analysis: if a governance form benefits the district as a whole but not individual groups, the latter would have an incentive to move towards individually more favorable forms. Investigating average fitness per group for each governance structure shows that being the leader firm always increases group fitness as compared to the collective case (see columns 2 and 4 in Table 1). For some parameter values (see columns 2 and 3 in Table 1, underlined values), groups exhibit a higher fitness in the case of alliances. It can therefore be concluded that the collective governance structure — while optimal for the district — does not maximize fitness for all groups. In some instances, groups can do better by building alliances and there is a fitness incentive for all groups to become the leader firm.

Alliance or leader firm scenarios can also be viewed as a good intermediate governance structure in another context. If for some reason the enforcement mechanism of collective observation and punishment in the district's local culture were insufficient to "guarantee" a collective orientation by all agents, the collective regime

Table 1. Governance structure and group fitness for selected C values.

$C = 0.67$	Collective	Alliance*	Leader firm**	Individualistic
Group 1	0.75065	0.74523	*0.75557*	0.74021
Group 2	0.73130	<u>0.73523</u>	*0.74039*	0.72711
Group 3	0.73066	<u>0.73717</u>	*0.74373*	0.72341
Group 4	0.73480	0.73127	*0.74978*	0.72405
$C = 6.00$	Collective	Alliance*	Leader firm**	Individualistic
Group 1	0.72029	0.71585	*0.77308*	0.69998
Group 2	0.71858	<u>0.73105</u>	*0.77814*	0.69914
Group 3	0.71866	0.71433	*0.77028*	0.69149
Group 4	0.71856	0.71308	*0.76932*	0.69213

*Between groups $1 + 2$ and $3 + 4$.
**In the respective group.

might be destabilized once deviants register (short-term) fitness gains in comparison to co-operating agents. It could be argued that in periods of stability, any deviation from collectivism would be discovered by its adverse effects on other agents and the district as a whole. The very nature of change, however, implies that this observation mechanism loses some of its accuracy. As change in the competitive environment reduces the fitness of the district, individual agents could defect, i.e. change their orientation and activity from collective to individualistic. To avoid punishment by other local agents, they could then ascribe the effects of their defection on other district agents to the change in the environment.

To test for this intuition, the simulation model was extended to include individualistic group behavior in otherwise collectively oriented districts. Simulations were run with an increasing number of individualistic agent groups (ranging from one to three). When comparing average group fitness in these mixed districts with those found for the pure individualistic and collective case, a strong *prisoner's dilemma* emerges (Fig. 6). In terms of average fitness, any agent group has an incentive to defect from the local rules of the game and act individualistically (see numbers in bold). At the same time, any district group suffers worst in terms of fitness if it cooperates (behaves collectively) but is exposed to defection (individualistic behavior) by its neighbor group (see numbers in italics).

Two neighbor groups are defined as the groups sharing the greatest interdependence due to C externalities. In the model set-up developed here, groups 1 and 2 are neighbors as are groups 3 and 4. If either of these groups starts behaving individualistically, the co-operating group exposed to an *individualistic neighbor* obtains a fitness value below that found in the fully individualistic case.[g] If group 1 behaves collectively (cooperates) and group 2 behaves individualistically (defects), the fitness value of group 1 is 0.72445 and that of group 2 is 0.75436 (top left cell in Fig. 6). The fitness value of group 1 when facing an individualistic neighbor is thus

<u>C=0.67</u>	Group 2 Cooperate	Group 2 Defect
Group 1 Cooperate	0.73130 0.75065	**0.75436** *0.72445*
Group 1 Defect	*0.72064* **0.76234**	0.72711 0.74021

<u>C=0.67</u>	Group 4 Cooperate	Group 4 Defect
Group 3 Cooperate	0.73480 0.73066	**0.75444** *0.71053*
Group 3 Defect	*0.71495* **0.74439**	0.72405 0.72341

<u>C=6.00</u>	Group 2 Cooperate	Group 2 Defect
Group 1 Cooperate	0.71858 0.72029	**0.77390** *0.65694*
Group 1 Defect	*0.66662* **0.77657**	0.69914 0.69998

<u>C=6.00</u>	Group 4 Cooperate	Group 4 Defect
Group 3 Cooperate	0.71856 0.71866	**0.77480** *0.65000*
Group 3 Defect	*0.66743* **0.77171**	0.69213 0.69194

Fig. 6. Group behavior and fitness (selected C values) — Prisoner's dilemma revisited.

[g]Of course, the performance of co-operating groups decreases even further as the number of individualistic groups in the district grows (results not reported here).

below the one (0.74021) in the fully individualistic case (both defect). The fitness value of group 2 is above the level obtained if both behave collectively (cooperate), which equals 0.73130. This constellation holds for all district groups over all model parameters.

In terms of group fitness, the following ranking therefore emerges: *Individualistic group* > *Collective* > *Individualistic* > *Individualistic neighbor*. In the presence of any C externalities between groups, individualistic behavior will thus spread in the district once one group starts behaving individualistically as each group "infects" its respective neighbor. One of the possible outcomes of such a development would be a shift from a collective to a fully individualistic governance structure. As the latter performs worst regarding system and group fitness in adaptation, agents in the district might be motivated to form hierarchies like alliances or dominant firms, where the corresponding agent orientations are easier to enforce. This helps them avoid the even deeper fall in fitness provided by a shift towards the individualistic regime.

4. Summary and Conclusion

This paper set out to investigate the role of governance in district adaptiveness and survival. Modeling districts as systems of interdependent agents and using Kauffman's N/K model to simulate their performance (fitness) in adaptation to external shocks led to several results. First, the importance of governance for adaptive performance increased with the role of cross-agent externalities. Second, the adaptability of districts depended on the extent to which their governance structure internalized cross-agent externalities into agent decisions. The collective and individualistic cases acted as benchmark scenarios with the former performing best in terms of results and stability of the adaptation process. Hierarchical governance structures (alliance or leader firm districts) positioned themselves between these two extremes. Their relative performance became more similar as cross-agent externalities increased. These findings were robust with respect to changes in agent numbers as well as for less drastic shifts in the fitness landscape (results not reported here).

While performing worse for the district than the collective governance, alliances and leader firms can still be more attractive than the former from a couple of perspectives, thereby providing one possible explanation for the shift in Italian districts towards both modes of governance. On the one hand, the collective case performs best in adaptation for the entire district, but not necessarily for all district groups. Some might fare better by forming alliances or by attempting to become the dominant agent. On the other hand, the collective case can be unstable: if local institutions are insufficiently strong to guarantee a corresponding mindset in all district actors, the collective case can easily deteriorate into the individualistic one — thanks to a prisoner's dilemma payoff structure in agent group fitness. In order to avoid this, district agents might move towards alliances or leader firms as more stable governance solutions, which guarantee better adaptation than situations where district agents act only in their own interest. As a result, the shift in governance structure in many Italian cases may be more desirable from the district's perspective than has usually been acknowledged.

The model developed here addresses the existing literature in a number of ways. First, it attempts to provide a more conclusive analysis of the role of governance in district adaptation than has been obtained in the existing (empirical) literature. It highlights when each of these governance forms steer individual agent adaptation towards good collective outcomes. In doing so, the model shows one possible rationale for the Italian district experience. Moreover, its results could serve as guidance for future empirical studies by highlighting causalities between governance structure and district survival that would invite further testing. Second, the research conducted here highlights that a Marshallian understanding of districts can be reconciled with a dynamic perspective of change and adaptation, a trend that is only beginning to enter the theoretic literature.

While the model generates a number of interesting results, it is not without limitations. As the model focuses on *district-level* factors steering individual activities towards good collective outcomes, important aspects shaping agent dynamics are not accounted for (e.g. organizational inertia or agent heterogeneity). Put differently, the model can show which governance structure will work well for a district *if* its agents behave in a certain way. Moreover, the intricate interdependencies between agents imply that model results are to be viewed as tendencies rather than deterministic predictions. For instance, even if collective districts perform best in adapting *on average*, districts with other governance structures might get lucky in individual adjustment processes.

In future research, a number of model extensions will emerge. The most important of these concerns the search mechanism used by district agents. As has been advocated in much of the literature applying the N/K model to the social sciences, random element mutation is not a realistic search process when agents are capable of conscious and deliberate activity. An interesting case thus concerns investigating how model results change if more elaborate search mechanisms are used. This could involve increasing the breadth and depth of search, i.e. the number of elements modified on the one, and the long-term perspective of search on the other hand (e.g. as in Refs. 22 or 23). A second aspect to be investigated regards the dynamics of governance structures, i.e. agent-based district models (as advanced in Refs. 5 and 44) leading to evolving governance structures in the district where moves between the different regimes become possible.

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