Resetting the Clock: A Feedback Approach to the Dynamics of Organisational Inertia, Survival and Change

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Introduction

Studying organisational change requires—almost by definition—a commitment to the analysis of dynamic processes and disequilibrium states. Yet, with few exceptions, our understanding of organisational change processes has have not progressed much beyond static (or comparative static) frameworks in which strategic change is seen as an almost instantaneous transition from one equilibrium configuration to another, with surprisingly little attention given to the multiple adjustment paths that may connect the two states, and to the disequilibrium states likely to be encountered along the transition process [1–3].

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The emphasis on equilibrium at the organisational level, and on its individual-level counterpart—optimisation—rests on what March and Olsen [4] have termed the assumption of 'historical efficiency,' or the belief that observed organisational configurations are the result of some (possibly optimal) adaptation processes [5]. One of the consequences of the ubiquity of the historical efficiency assumption in the study of organizations is that: 'While there has been considerable progress in developing frameworks that explain differing competitive success at any point in time, our understanding of the dynamic processes by which firms perceive and ultimately attain superior market positions is far less developed' [6].

These considerations are at the core of a dynamic theory of organisations because it is well documented that organisational structures respond with significant delays to managerial attempts to modify their core features [7], and because competition strengthens both the focal firm and its rivals, resulting in a race where competitors consume their resources just to maintain their relative position [8]. Jointly considered, the presence of time delays in managerial responses, and the self-reinforcing quality of many competitive processes, can be taken as points of departure to explore a wide range of long standing theoretical problems related to the actual degree of responsiveness of organisational structures to managerial action [9]. In this process oriented perspective, the possibility of influencing the dynamics of strategic and organisational change hinges on the understanding of how organisational structures operate over time to defeat—or catalyse—the efforts of policy makers, managers, and planners aimed at reforming organisations. But how should the effect of managerial change attempts on actual organisational change and survival be conceptualised, given the tendency of organisational structures to absorb and dissipate part of the energies and resources devoted to change?

Research in organisational ecology instructs us that change is hazardous because failure may result both from the misperception of the need for change—and hence inaction—as well as the disruptions and uncertainties introduced by the process of change itself [10, 11]. The problematic relationship between strategy conception and execution on the one hand [12], and between strategy execution and its consequences on the other [13], is rooted in the observation that business organisations exhibit many of the characteristics of policy-resistant dynamical systems [3, 14, 15]. However, resistance to change does not necessarily imply that organisations never change, or even that change is infrequent. Organisations do change considerably over time [16] and at times they are able to do so rather creatively [17]. Organisational inertia—like performance—is a relative, rather than an absolute concept and questions arise about how fast established organizations can change to address current needs and capture—or build—new resources.

Against this general background, in this paper we take the theory of structural inertia proposed by Hannan and Freeman [10] as the starting point to develop a dynamic feedback model of organisational inertia and change. We use system dynamics (SD) to simulate the model, test its internal consistency, and explore the full dynamic implications of structural inertia theory. While the application of system dynamics to specific policy and management problems is not new [18–21], its potential as a method for building and testing organizational theories remains largely unexplored [22]. Relatively few examples are available of SD as an aid to theory building and theory testing. One such example is Sterman's [23] attempt at formalising and test Kuhn's theory of scientific revolutions. Another example is Hanneman et al. [22] recent development of a model of state legitimacy and imperialist capitalism. A third example is Sastry's [24] reconstruction of earlier conceptual work on convergence and upheaval in processes of organisational change. Other examples of SD concepts applied to theory building and model conceptualisation include Masuch's [19] work on vicious circles in organisations as particular instances of positive feedback processes, and Hall's early work [18] on the dynamics of organisational pathologies. However, many other cases can be identified in which explanations for particular institutional and competitive phenomena in the organisational world are proposed that hinge implicitly on SD arguments [25, 26]. We find this relatively infrequent application of SD methods to theory building in organisational research surprising mainly because SD methods provide excellent opportunities to: (i) formalise propositions expressed in natural language within more articulated theoretical frameworks, while maintaining the richness and ambiguity of social theories and testing their dynamic consistency; (ii) explore the implications of alternative ways in which theoretical propositions might be linked, and (iii) go beyond the unconvincing image of theory testing as the examination of a series of sequential single-proposition statements about complex social and organisational processes.

Our general goal of this paper is to illustrate the value of system dynamics as a method for theory building and testing in the context of a central debate in current organisational research. A second—and somewhat narrower—objective of our paper is to present a modeling framework that may help organisational theorists and analysts to overcome some of the specification problems typical of empirical research on organisational survival and change inspired by ecological theories of organisations. In this line of empirical work on the causes and consequences of organisational change, it is not always easy to separate dependent from independent variables, and estimation of complete models is often problematic [1]. As, a consequence, many of the complexities arising from the dynamic nature of the theory of structural inertia need to be greatly simplified in order to arrive at estimable statistical models. With this work we hope to be able to establish a structured framework that will help to improve our understanding of the dynamic organisation-level processes that regulate the vital dynamics of individual organisations and that shape the evolution of organisational populations over long periods of time.

A Feedback View of Organisational Inertia and Change

Structural Inertia Theory

Starting from the notion of organisations as change-resistant complex systems for which structural change is at least as risky as stasis, the theory of structural inertia originally proposed by Hannan and Freeman [10] provides a structured framework for thinking about how processes of organisational change unfolds. The theory identifies reliability and accountability as the primary sources of survival advantage for modern complex organisations. Reliability means that organisations are rewarded for reducing the variability of the product or services supplied, and for fulfilling customers' expectations in terms of quality, timing and prices of products. Accountability means that organisations are rewarded for their ability to document how their resources are allocated, and for convincing members, investors and clients of the procedural rationality of the decisions behind specific outcomes. Reliability and accountability are high when organisational goals are institutionalised and activities routinised, but institutionalisation and routinisation also generate inertial pressures because they encourage replication and exploitation of existing competencies [27].

According to Hannan and Freeman [10] structural inertia is not constant over the organisational life-course, but varies systematically with age and size. Specifically, organisational reliability and accountability are assumed to increase monotonically with size and age. Given that resistance to change also moves in the same direction of reliability and accountability over time, it follows that the probability of change decreases as organisations grow older and presumably bigger. Figure 1, taken from Kelley and Amburgey [28] illustrates the basic logic behind the theory of structural inertia as a series of dyadic connections among the core theoretical constructs. The empirical specification of dynamic models of organisational survival and change typically conforms to this sequential linear structure which allows—at least in principle—each individual causal links between the independent and the dependent variable to be empirically assessed given data on a suitable number of organisational life histories.

If we accept it as plausible, the theory of structural inertia has two main counterintuitive implications for our understanding of organisational change. The first is that the same characteristics that give organisations a

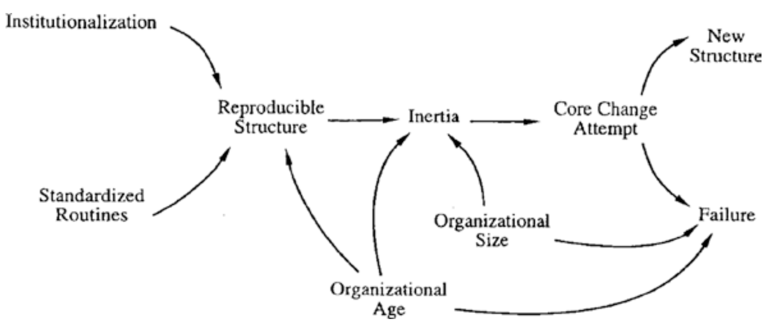

Fig. 1 Structural inertia theory as a series of individual propositions [28]

survival advantage also make them more resistant to change. It follows that selection processes tend to favour organisations that are relatively inert. This conclusion is clearly at odds with the suggestions offered by textbook views of organisational change that tend to see flexibility—rather than inertia—as the key to organisational performance and long-term survival. The second implication is that organisational change is risky in and for itself because it disrupts the routines in which organisational memory and competencies are stored [29], and calls into question the (internal and external) bases of institutionalisation and legitimation [30, 31]. As a consequence, organisations in the process of fundamental transformation are 'between a rock and a hard place' in the sense that change processes themselves may increase organisational failure rates independent of their content, that is, of whatever organisational characteristics are being changed [11, 32]. To the extent to which young organisations are exposed to a 'liability of newness', the tendency of organisational failure rates be higher in the early stages of organisational life and to decline with age [33], major structural changes imply that established organisations may once again be exposed to the causes of failure typical of young organisations, like, for example, the need to establish a framework of trust within which strangers can cooperate and agree on the appropriate sanctions for opportunistic behaviour, and the lack of consistent solutions to routine problems [31]. In this sense, major organisational changes can be said to 'reset the clock' that regulates the vital dynamics of individual organisations and increase, at least temporarily, the hazards of failure [11, 30].

To date, only few empirical studies are available that explored the effects of change and 'resetting the clock' on organisational survival. This situation reflects both the relative novelty of the framework, as well as the problems related to the identification and estimation of possible underlying statistical models that can disentangle the individual effects of change contents and processes [1]. According to the theory, process effects of change on organisational mortality are positive, but content effects can be negative *or* positive, hence it is difficult to estimate the individual effects due to the former (process of change) while holding constant those induced by the latter (content of change). As it could perhaps be expected under these circumstances, received empirical evidence is mixed: while one study supports selected aspects of the theory like, for example, age dependence in failure rates [11], other studies report change effects that are strongly contrary to the theoretical predictions [28, 34].

The theory of structural inertia can be seen as a dynamic theory with multiple feed back loops that are both explicit as well as implicit in the original formulation. On the one hand, the presence of multiple feedbacks is fully consistent with the process view or organisational change underlying the theory, but on the other hand, the sequential version of the model used in empirical studies (and summarised in Fig. 1) does not adequately capture the complexity of the relationship between organisational inertia, change and survival implied by the theory. In the following section, we present a fully dynamic version of the structural inertia model in order to (i) explore the internal consistency of the underlying theory; (ii) understand the dynamic feedback structure behind processes of organisational change; and (iii) explore the relation between organisational change, experience and survival in order to clarify some fundamental organisational level process that may be consistent with what we know about the ecological dynamics of organisational populations.

Resetting the Clock: A Feedback Model

The causal loop diagram in Fig. 2 connects three of the central concepts in the theory of structural inertia: inertia, performance reliability and change attempts. Inertia affects change attempts negatively, and change attempts decrease reliability because they disrupt internal and external networks in which organisations are embedded [11]. Finally, due to the

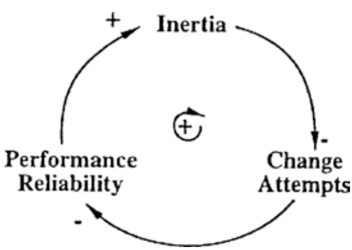

Fig. 2 A positive feedback loop which increases (or decreases) inertia

high degree of replicability and routinisation needed to stabilise performance over time [10], reliability increases organisational inertia. This first loop implies that a positive feedback process is at work to increase the level of organisational inertia over time. According to the theory, structural inertia reduces the number of change attempts, and this will result in higher reliability, that is, improved ability to reproduce past behaviour. But reproducibility induces further increases in inertia. The dynamic behaviour generated by the positive feedback process implied by this first causal loop is exponential growth.

But what are the limiting factors that prevent organisational inertia from increasing indefinitely? It is not easy to find an explicit answer to this question in the ecological literature on organisational change. The causal loop diagram reported in Fig. 3 illustrates a negative feedback process that may possibly limit the accumulation of structural inertia over time. According to the diagram, as inertia increases the likelihood of successful change becomes smaller. In turn, prolonged periods of stasis will increase the pressure for change in the organisation. As pressure for change increases, it is reasonable to expect that at least some new change attempts will be made. According to the theory, repeated attempts at changing organisational structures and processes decrease reliability and reset the internal organisational 'age clock.'

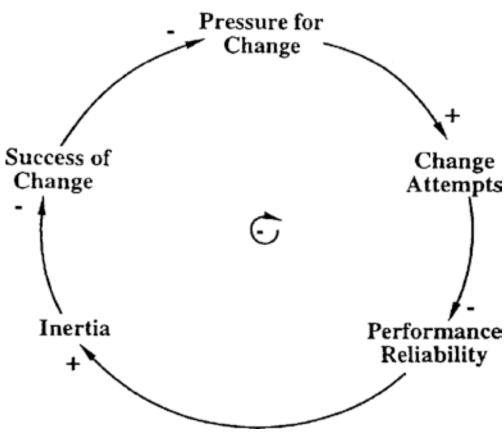

Fig. 3 A negative feedback loop which controls the growth of inertia

Complexity in dynamic feed-back models is introduced by the number of loops, and the way in which the loops are coupled. In fact, while individual loops may give rise to predictable dynamic behaviour (exponential growth or decline), it becomes almost impossible to predict the behaviour of a system with four or more feedback loops. In this sense, the theory of structural inertia can be viewed as a complex statement about the processes responsible for organisational change, resistance to change, and failure. The empirical studies available have tested individual propositions derived from the theory, but in order to understand its full dynamic implications, we have to represent the theory of structural inertia as a system of interdependent statements, that is as a system of equations rather than a sequence of separate 'hypotheses.' Figure 4 contains the complete feedback representation of the theory of structural inertia that we develop in this paper. In the figure, the letters and numbers reported on the directed lines connecting the variables refer to the assumptions (*A*) and the theorems (*T*) as they are, respectively, imposed and derived in the original formulation of the theory [10].

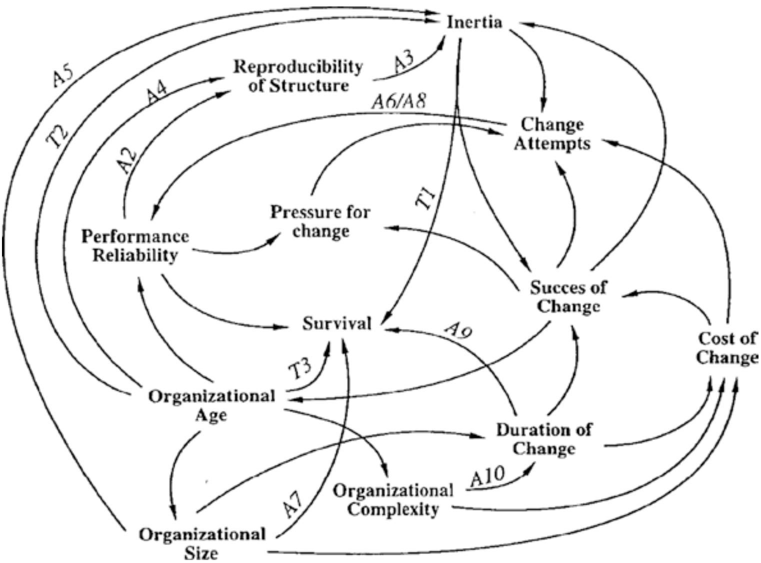

Fig. 4 Complete conceptual feedback diagram of structural inertia

For example, *A5* placed along the line connecting *Organisational size* and *Inertia* indicates that according to *Assumption 5* in the theory: 'The level of structural inertia increases with size for each class of organisation.' (Hannan and Freeman [10], p. 158). Similarly, *T*3 placed on the line going from *Organisational age* to *Survival* indicates that, according to *Theorem 3* in the theory: 'Organisational death rates decrease with age' (Hannan and Freeman [10], p. 157). In Fig. 4 we note that all of the ten assumptions underlying the theory are represented, with the only exception of assumption 1 according to which 'Selection in populations of organisations in modern societies favours forms with high reliability of performance and high levels of accountability' ([10], p. 154). This assumption that in a fundamental way, motivates the whole ecological theory of structural inertia and change, is not directly representable because it is based on the population-level concept of 'selection,' while in this paper we concentrate on organisational-level processes. In other words, in our model we try to specify possible firm-level processes that are consistent with the macrolevel relationship between accountability, reliability and selection observed in the study of the dynamics of organisational populations.

Finally, we note that all of the 5 theorems in the theory are represented, even if theorems 4 and 5 can be derived only indirectly. Theorem 4 (according to which 'Attempts at reorganisation increase death rates' [10], p. 159) is represented indirectly because we portrayed the effects of *Change attempts* on *Survival* as mediated by the possible deterioration in *Performance reliability* that may be induced by reorganisation. In other words, our representation does not rule out *a priori* the possibility of beneficial content effects of change. Similarly, theorem 5 (according to which 'Complexity increases the risk of death due to reorganization' [10], p. 162) is also represented indirectly in Fig. 4 because we were reluctant to specify *Complexity* as a *direct* cause of mortality for organisations that are undergoing change, and because the theoretical literature offers conflicting suggestions on the relation between organisational complexity and performance [35–37]. Rather, we saw *Complexity* operating on organisational mortality through intermediary factors such as the *Duration* or *Cost of change.*

Obviously, at this level of generality nothing is being said about exactly how the different concepts in the theory are related, that is, about the functional form of the relationship among variables. This will be done in the next section in which we formalize the feed-back structure of the theory of structural inertia, and translate it into a system of difference equations represented as a series of interlinked stocks and flows diagrams. This will be the last step needed before the actual simulation of the dynamic behaviour of the system.

From Feedback Loops to Dynamic Models

Before moving on to the detailed description of model specification, it is important to emphasise that our goal is *not* to provide a realistic model of inertia and change in a specific (or even 'representative') organisation, but rather to provide a system dynamics model of a *theory* of organisational inertia and change. For this reason we are searching for a minimal model specification that may allow us to explore the dynamic implications of the theory, and test its internal consistency. With this goal in mind, in this section we will discuss the critical parts in the formulation of a relatively small system dynamics model of inertia and change. The final model will contain 31 variables expressed as a system of differential equations. The reduced-form of the model includes 5 differential equations, but in this form, each individual equation would not lend itself easily to interpretation.

As Fig. 5 illustrates, structural *Inertia* is formulated as a stock (or 'accumulator') variable. In practice, this means that inertia can be accumulated

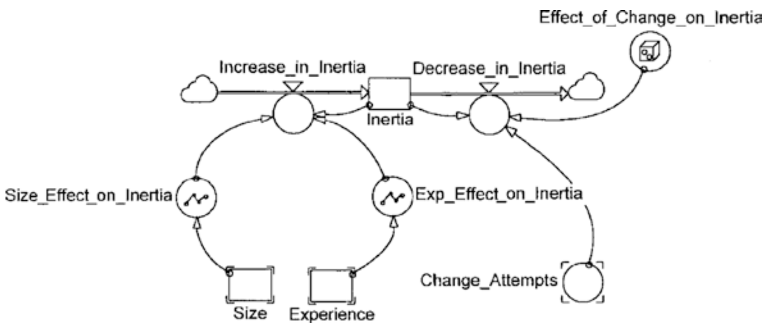

Fig. 5 The formulation of inertia in the model

over time; it can both increase, as well as decrease depending on the dynamics of the two corresponding flow variables (*Increase in Inertia* and *Decrease in Inertia*) indicate. *Inertia* is measured in dimensionless units through an index function. In the version of the model that we present, we assume that change attempts are intendedly adaptive and have the basic objective of decreasing structural inertia, that is making the organisation more responsive to changes in whatever contingencies management considers relevant. In practice, this goal may or may not be achieved depending on the effects of a number of other factors. These other factors are captured by the variable called *Effect of Change on Inertia*. This is modelled as a normally distributed stochastic term that determines the actual magnitude and direction of the impact of change attempts on structural inertia, which may range from almost null (change attempts have no implications for inertia), to strongly negative (change attempts decrease inertia, and reset the organizational age clock).

In keeping with the original formulation of the theory, structural inertia is affected by organisational age and size. To model these effects we use what is referred to as 'graphic converters' which specify the functional relationship between age, size and organisational inertia as a graph function. These qualitative relationships are represented in Fig. 6. Graphic converters make it exceedingly simple to test the modelling implications

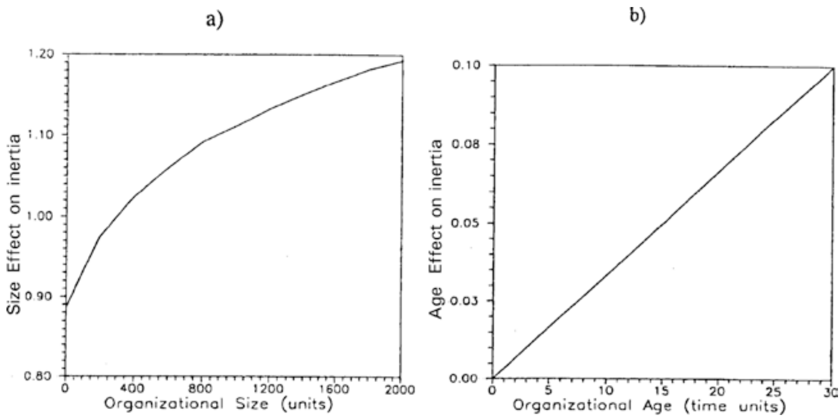

Fig. 6 Two examples of graph functions in the model, (**a**) the relationship between size and inertia, and (**b**) the relation between age and inertia

of a variety of functional links between age, size and organizational inertia—a problem that invariably comes up in empirical research, but one that does not have a direct empirical solution. The consequences of non-proportional effects of size are shown in Fig. 6a which implies some sort of diminishing effect of size on inertia. Simply put, an increase in organisational size from, say 10–20 has a larger effect on inertia than an increase from 1200–1210. The implications of a simple linear relationship are reported in Fig. 6b.

In Fig. 7 we illustrate how the pressure for change—represented as a stock variable—builds up and how it eventually generates change attempts. We assume that *Pressure for Change* increases when there is a gap between the *Expected* and *Actual Reliability*. Any difference between the expected and actual reliability will cumulate into additional units of *Pressure for change*. *Expected Reliability* is modeled as a combination of the expected *Trend in Reliability* (a terms which implies that past accomplishments provide at least some information about future accomplishments) and a 'stretch' parameter. The 'stretch' parameter indicates how much the organisation is expected to improve its *Reliability*, independent of past performance.

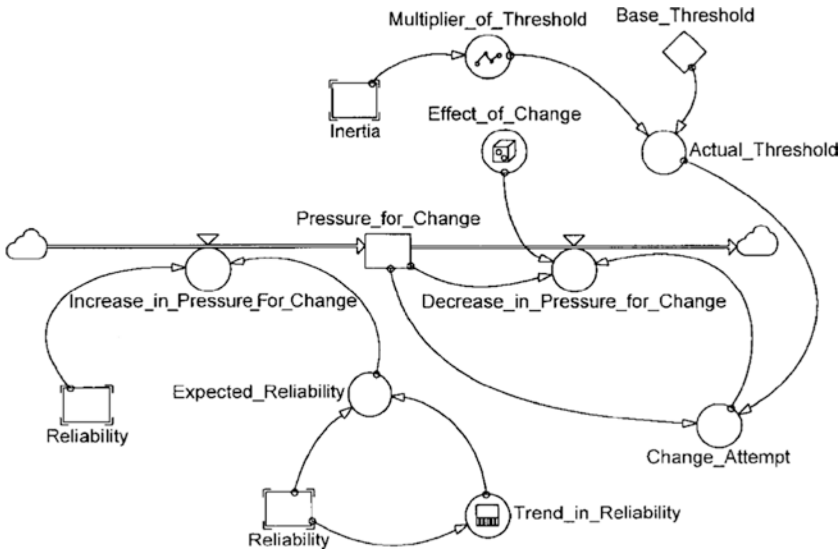

Fig. 7 The formulation of pressure for change and change attempts in the model

In Fig. 7, *Change Attempts* are modelled as a threshold function according to which change attempts will be made whenever the pressure for change reaches a given threshold value. However, the value of the threshold is itself dynamic, and fluctuates over time around a given 'base threshold.' The actual value of the base threshold changes as inertia increases so that the pressure for change needs to increase further to trigger new change attempts. *Change Attempts* work to release some of the accumulated *Pressure for Change* through the outflow *Decrease in Pressure for Change* How effective a change attempt is depends on a number of external and internal circumstances. As before, we use a stochastic variable called *Effect of Change* to reflect this basic indeterminacy in processes of organisational change. Some change attempts will be very successful and pressure for change will drop dramatically, while other attempts might do very little for releasing pressures for change.

Figure 8 shows the dynamics of reliability. *Reliability* is a complex construct presented as the joint consequence of routinisation, formalisation and institutionalisation [10]. To make the concept of reliability more specific, we simply model it as the inverse of 'variability,' which is itself a function of organisational experience and size, plus an exogenous baseline variability level that is always present in organisations. As the organisation grows older, gains experience and becomes larger the initial variability in production activities and quality decreases due to routinisation and

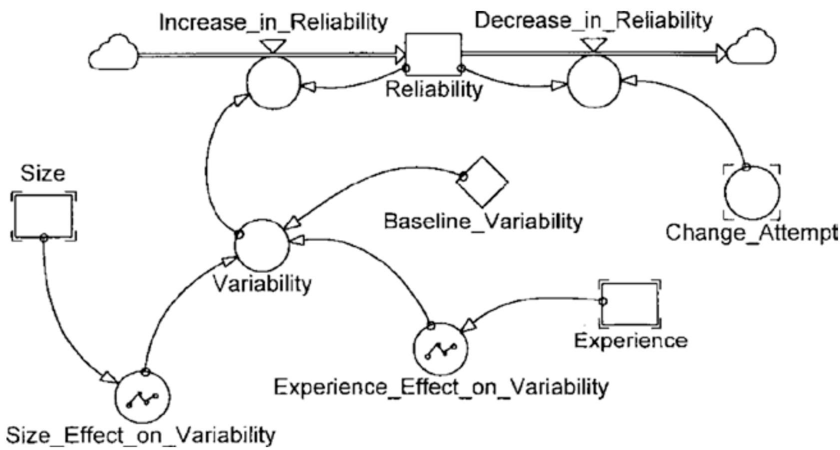

Fig. 8 The formulation of reliability

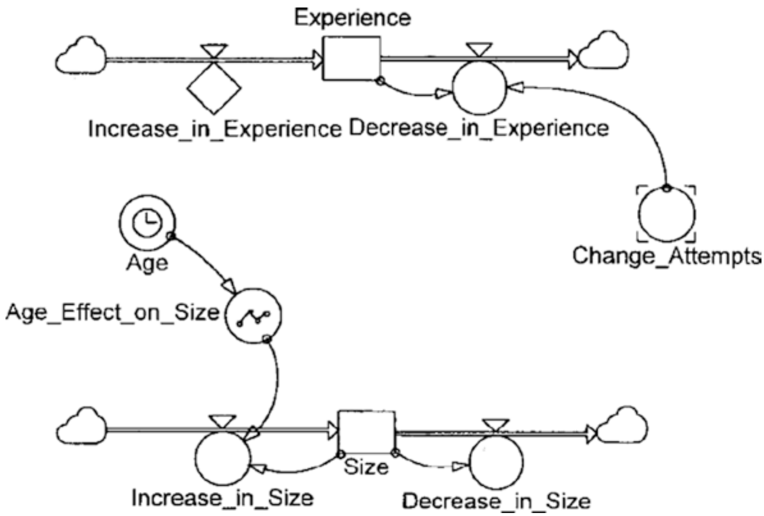

Fig. 9 The formulation of organisational experience and size

learning. As before we use 'graphic converters' to specify the qualitative relationship between the value of experience, size and variability.

In Fig. 9, *Organisational Experience* and *Size* are modelled as stock variables that may increase or decrease over time. We assume a systematic connection between organisational size and age, represented in the model by the graphic converter called *Age Effects on Size*, in which age coincides with simulation time. We chose to define the organisational age clock in terms of value of *Experience* in order to avoid any confusion with the typical meaning of the word 'age.' In this sense, major organisational changes 'reset the clock' to the extent to which they make accumulated experiences, competencies and knowledge obsolete [38]. In keeping with the original formulation of the theory, we use a graphic converter to define organisational size as a monotonically increasing function of age [10], but a wide range of different assumptions about the functional form of this relationship could be formalised to capture specific effects related to processes of organisational learning.

Finally, Fig. 10 illustrates the complete structure of the model that we simulate and analyse below. The complete system of equations that is implied by the diagram contained in Fig. 10, and the specific numerical values used to initialise the system are reported in Appendix.

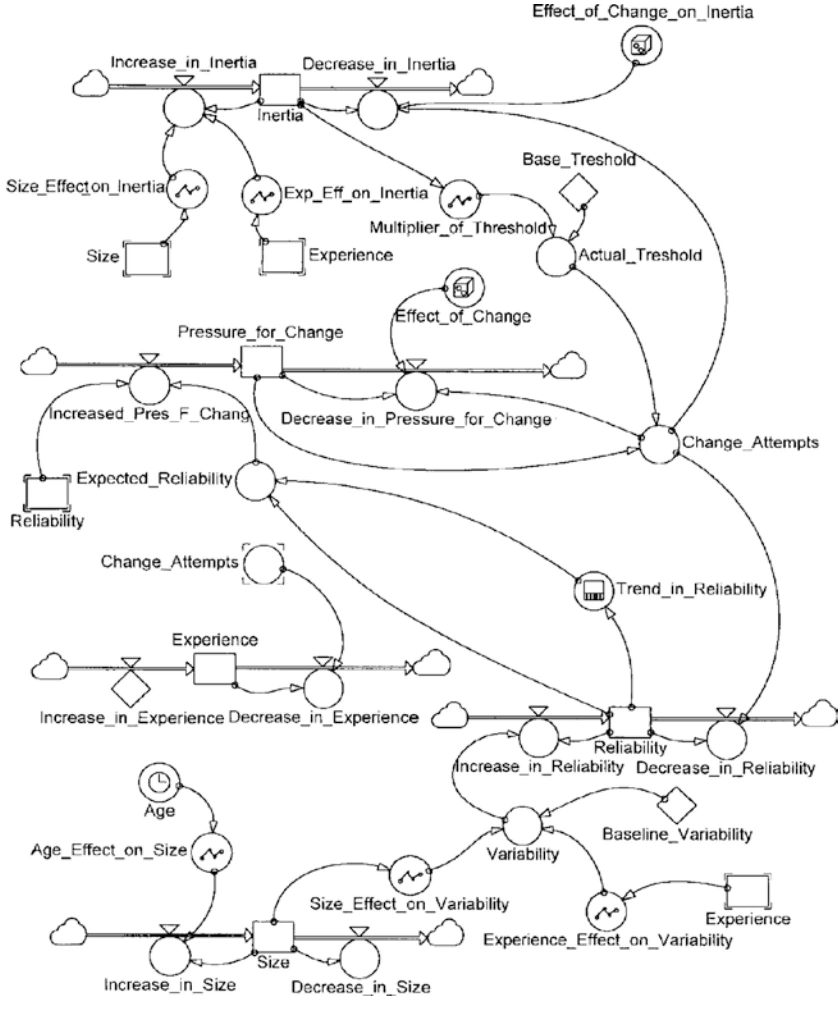

Fig. 10 The complete model

Methods

We rely on system dynamics (SD) to explore the qualitative dynamics of organisational inertia and change implied by ecological theories of organisations because we see three main advantages of SD in the analysis of organisational evolution in the context of the theoretical tradition in which the paper is rooted. Firstly, nonlinearities and disequilibrium assumptions are easily incorporated into SD models and this makes it possible to test for a wide range of possible relations among the factors that underlie change processes. Secondly, SD models allow to analyse the role of time delays explicitly, therefore allowing to explore different ways in which inertia operates on organisational structures. Thirdly, the focus on feedback processes in which individual variables are embedded makes SD particularly useful as a way of representing situations characterised by a systematic interdependence among co-occurring causal factors. While many contemporary theories of organisations suggest that nonlinearities, disequilibrium states, delayed effects, and feedback processes should be at the heart of our understanding of organizations and institutions [4, 5, 39], empirical research is often unable to sustain the analytical complexities implied by these theoretical suggestions.

Simulating Organisational Theories

There are three main motivations for relying on simulation rather than direct data analysis to explore the dynamics of the ecological theory of organisational inertia, survival and transformation. Firstly, the formulation of the hypotheses for the purpose of empirical data analysis encourages a fragmented and (comparative) static view of theoretical systems. As Sutton and Staw put it: '[H]ypotheses can be part of a well crafted theoretical argument [...] but hypotheses do not (and should not) contain logical arguments about why empirical relationships are expected to occur' [40]. To our mind, this is precisely what makes computer simulation as useful as systematic empirical research for extending and testing organisational theories [41]. In a view of 'theory as narrative' [12], it makes little sense to extract and test individual propositions because what makes a theoretical narrative valuable is the way in which these propositions are interlinked. The statistical machinery used in empirical research is functional to what we can call a single-proposition approach to the study of organisations. This is unfortunate because it forces researchers to ignore what makes organisations an interesting and challenging object of study, such as for example, the lack of a clear *a priori* distinction and sequential dependence between dependent and independent variables, the presence of multiple time delays that characterise economic and social relations, and the complex structure of feedback processes in which the 'dependent' variables are embedded [43].

Secondly, theory discovery and testing by computer simulation is particularly useful when the existence of equilibrium points is less substantively important (and/or theoretically interesting) for the understanding of the social or economic system under study than the trajectories connecting these points and the speed at which the system converges to (or as the case may be, moves away from) specific equilibrium states [22]. Computer simulation becomes practically useful as a tool for theory building when: '[T]he guiding frame is that of a world of processes unfolding in time and flowing back upon each other' [22] that is when attention must be paid to the historical dynamics behind the observable outcomes of institutional and competitive processes. In this sense, simulation holds great promises for going beyond the unhelpful distinction between 'quantitative' and 'qualitative' approaches to the study of organisations, and therefore facilitating the composition of an artificial distinction that is one of the most enduring sources of disagreement about what exactly counts as 'theory' in organisational research [44].

Thirdly and more specific to the current work—a wide range of simulation methods are gaining legitimation as means of improving our understanding on key theoretical issues in organisational ecology research such as the relationship between diversity and competition [45], learning and evolution [46], adaptation and selection [47], and growth rates and organisational size distributions [48]. Computer simulation is also increasingly common as a means of testing the qualitative long-term implications of empirical estimates [5, 49] and as a tool for the rigorous development of theories concerning problems that resist direct empirical investigation like, for example the role of unobserved heterogeneity in organisational mortality rates [50, 51], the evolutionary implications of adaptive learning processes [52], and the role of micro-connectivity in the evolution of organisational populations [53]. Finally and very much in the spirit of the current work, ecological theories have been recently represented as computer models and evaluated by automatic theorem-provers through the development of logical formalism and language [54]. In most of these cases, computer simulation has helped to generate new theoretical insight, increase the coherence and focus of empirical research, and understand the qualitative implications of quantitative estimates. Obviously, these considerations do not imply that alternative ways of thinking about organisations cannot benefit from simulation in the same way, and perhaps even more. Rather, this literature suggests that ecological theories tend to be particularly good candidates for the development of simulation models due to their relatively high degree of formalisation, and the insistence of their proponents on comparability and cumulation of results across different studies as desirable properties of empirical research [55].

In closing, it may be worth mentioning that at no point in the present work we portray simulation as an alternative to well-crafted empirical research. Rather, we think of computer simulation as a way of exploring the dynamic implications of theoretical narratives, and therefore as a way of strengthening the link between organisational theories and history.

Results

Figure 11 shows the behaviour of the model during the first 20 time units periods. The *Variability* in the organisation decreases in an exponential fashion over time. In this specific case, the variability decreases almost by 50% over the first 20 time periods. As a direct consequence, reliability increases monotonically over the same period. *Expected Reliability* is a variable derived by extrapolation from *Reliability*.

Differences between *Reliability* and *Expected Reliability* create tensions in the organisation, this tension slowly is converted into *Pressure for Change* (Fig. 11d). The pressure for change eventually triggers *Change Attempts*. However, as the pressure for change gains momentum, inertia increases the *Threshold for Change*. Hence, change will happen depending on the relative speed at which these two quantities move over time. As Fig. 11e shows, inertia grows exponentially which implies that change is relatively easier to achieve in the early stages of organisational life, but becomes progressively harder as organizations age.

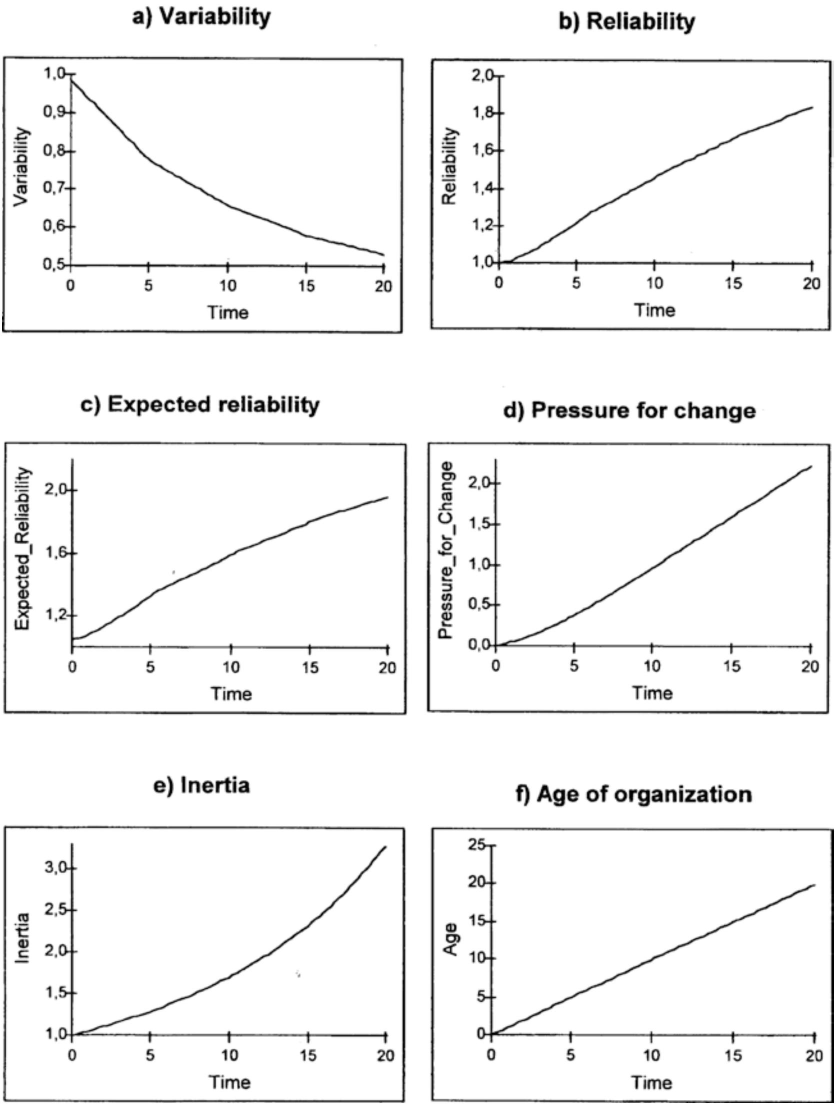

Fig. 11 Results from a 20 period simulation

Figure 12a–f illustrate the simulation results after 100 time periods. After the initial fall in variability and the corresponding increase in reliability in Fig. 12a, b, reliability tends to stabilise at relatively high levels

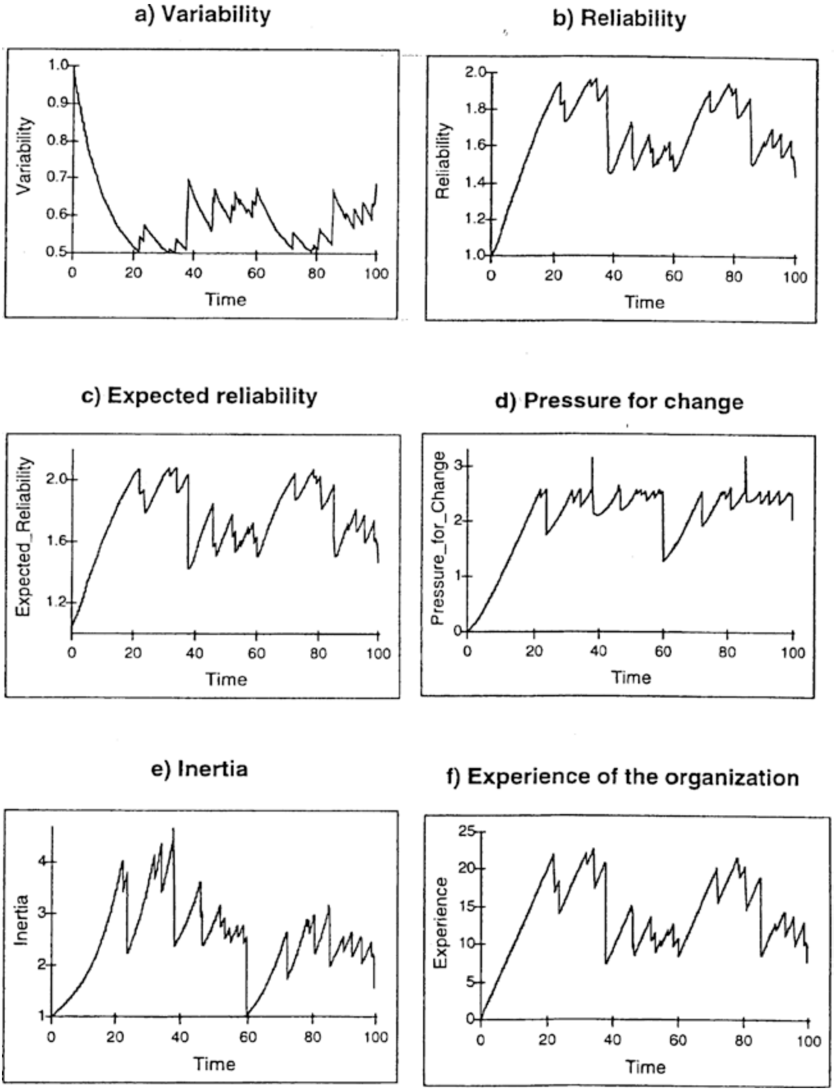

Fig. 12 Results from a 100 period simulation

for the following 20 simulation periods. During the same period inertia fluctuates between 2.5 and 4 with two identifiable long cycles—these figures being interpretable only in a relative sense, given that *Inertia* is a dimensionless index function by construction. As we reach period 40, a major change event drives inertia down, resulting in a sudden increase in variability (and corresponding drop in reliability). Interestingly, this change never had any long-term influence on the pressure for change, which remains roughly at the same level, despite the drop in inertia and accumulated experience in the organization. It is not before 60 time periods that another organisational change attempt reduces the pressure for change, in this case by more than a factor of two. Consequently, inertia drops dramatically from around 2.5 down to 1. At this point the organisation is almost back to its starting point, in the sense that inertia is reset to its initial value. During the process of change, the organisation has managed not to dissipate all the value of its previous experience, that decreased by factor of four between period 20–40.

From period 60–65 the organisation reaches the levels of experience and reliability that it originally had. As we mentioned before, pressure for change grows along with inertia, which means that the actual threshold also increases making change attempts less likely depending on the relative speed of these two quantities. Between period 65–80 we can observe a spell of relative stability (much like the period from 10–40). Around period 80, another major change attempt is taking place in the organisation, and again the value of experience drops to half of its previous value and reliability drops similarly. It is worth noticing that the organisation tends to get locked into quasi cyclical patterns of performance reliability over time. Obviously these cycles may not be observable for organisations whose survival threshold—defined in terms of an unobservable level of reliability above which the organisation is exposed to very high risks of failure—is sufficiently low.

We conclude our analysis by exploring the qualitative implications of alternative ways of representing the relationship between organisational experience and inertia or in other words between the accumulation of organisational competencies, and the tendency of the organisational structures in which these competencies are encoded to become more resistant to change over time. In Fig. 7 the *Trend in reliability (TIR)* operator captures the attitude of the organisation toward its own past performance (defined in terms of reliability), that is, defines the value of experience for the organisation. Formally,

$$TIR = \left[\frac{\mathrm{d}\left(\overline{R}\right)}{\mathrm{d}t} \frac{1}{\overline{\overline{R}}} \right]; \frac{\mathrm{d}\overline{R}}{\mathrm{d}t} = \frac{R - \overline{R}}{T\left(\overline{R}\right)},$$

where $\overline{R}$ is the average (or 'expected') reliability calculated as a first order exponential smoothing of the observed level of reliability (*R*), and $T\left(\overline{R}\right)$ is defined as '*Time to Average*,' a constant term that may vary significantly across organisations and that could be interpreted as the extent to which the organisation is subject to short term pressure on performance. If the value of $T\left(\overline{R}\right)$ is small, management will put a strong emphasis on most recent results, and consider them as a benchmark to evaluate current performance. As a consequence, as *actual* performance starts drifting away from *expected* performance, pressure for change will build up relatively fast forcing management to take immediate action. Figure 13a, b report the results of simulations in which $T\left(\overline{R}\right) = 1,3,$ and 5 respectively. All simulations performed previously assumed $T\left(\overline{R}\right) = 3$ (for details see the equation defining *Trend in Reliability* reported in Appendix).

During the first 20 periods, organisations characterised by different time orientations do not differ significantly. However, organisations with shorter-term orientations exhibit lower levels of inertia after period 40. As inertia decreases, the threshold for change decreases making future change more likely. Short-term pressures to meet performance expectations keep inertia low but tend to lock the organisation into a situation in which competencies are hard to build and preserve because change generates more change. As Fig. 13b illustrates, the level of competencies (or cumulated experience) of the organisation characterised by $T\left(\overline{R}\right) = 1$ is about half the level of competencies of the organisation in the baseline case (for which $T\left(\overline{R}\right) = 3$), and at times it drops to zero which correspond to a complete resetting of the clock that regulates organisational survival according to ecological theories of change. As expected, the opposite result obtain when we set $T\left(\overline{R}\right) = 5$. The main effect of a longer 'time drag' is to decelerate the cumulation of pressure for change. As a consequence, inertia will reach relatively high levels before change attempts become unavoidable. An interesting point to note is that an organisation that evaluates its current performance relative to performance levels

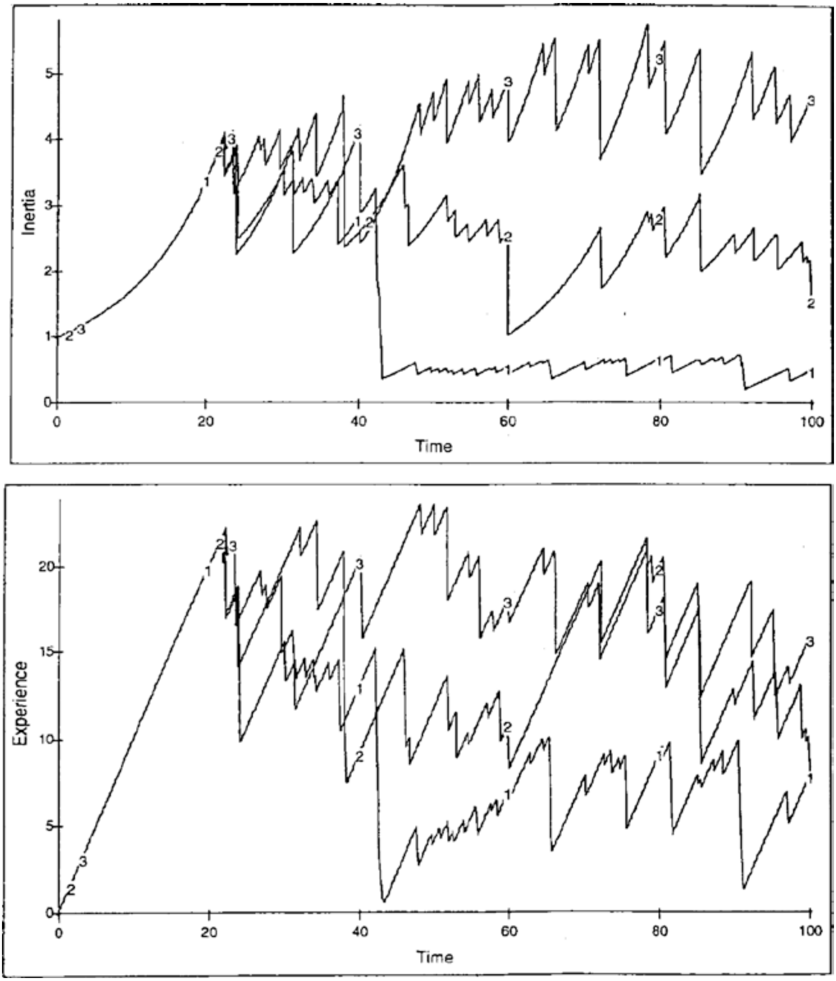

Fig. 13 The effect of time pressure on inertia and experience

reached in a less recent past (because $T(\bar{R}) = 5$) builds up competencies faster than a similar organisation, but with a shorter-term orientation (because $T(\bar{R}) = 3$). However, interorganisational differences in accumulated competencies tend to vanish after time $t = 60$, indicating the existence of an optimal (or 'ideal') level of resistance to organisational change. Below this point organisations change rapidly, but find it very difficult to stabilise their knowledge. Above this point, relatively high levels of organisational inertia are not compensated in the long run by a parallel accumulation of competencies and increase in reliability.

Discussion and Conclusions

According to one view of the organisational world, as organisations grow old and large they accumulate competencies, resources and knowledge that can be deployed to sustain and improve their competitive position. An alternative view suggests that as organisations grow old and large, their structures become progressively more vulnerable to processes of self-reproduction that dissipate resources and decrease their ability to respond adequately to the challenges of innovation and change posed by new rivals [56]. Which of these to views is more realistic depends on assumptions about *organisational inertia*, that is, about the relative speed (and cost) at which (i) organisational structures can be changed to address emergent needs; (ii) established organisations can move to occupy new resource spaces; and (iii) pre-existing corporate actors can generate and retain new resources internally. For these reasons the notion of structural inertia is central to our understanding of the dynamics of organisations and competition.

In this paper we concentrated on the part of population ecology theories of organisations that more directly deals with organisational inertia and change, and reformulated some of the central assumptions and propositions in system dynamics terms. We selected this specific theory of organisations because the clarity of its original formulation makes it particularly suitable to formalisation. One of the main motivations for translating the ecological theory of structural inertia into a system dynamics model was that empirical studies that have attempted to test the theory directly have been forced to ignore the complex feedback structure linking individual propositions for the purpose of specifying estimable statistical models. Perhaps the main motivation for the modelling exercise that we presented was our conviction that this 'single proposition' approach to organisational research greatly reduces the complexity, and intellectual value of theoretical narratives developed to account for relevant features of the organizational world. By using simulation methods we could exploit the rich dynamic feedback structure implicit in the original formulation to test its internal consistency, and explore the link between organisational inertia, the value of organisational experience and change.

The results reported suggest three main dynamic implications of the ecological model of organisational change. Firstly, organisational structures need to be in place before competencies can be created and resources built. In our models this conclusion is supported by the fact that structural inertia (which is linked to organisational size and age) builds up faster than organisational experience (which is dissipated—at least in part—by change attempts). We take this as supporting evidence for the proposition that routinisation of procedures, formalisation and investments in the other factors typically seen as determinants of organisational inertia, are needed *before* the organisation can exploit its knowledge, activate its resources, and build its competencies. In a world in which selection is based—at least in part—on reliability of performance, accountability of decision processes and reproducibility of structures, organisations that manage to reduce the variability of the products supplied or services rendered, stabilise their quality and fulfill customers' expectations in terms of timing and prices, may enjoy a significant competitive advantage over less reliable rivals. To the extent that reliability can be seen as a cumulative property of processes of exploitation of existing competencies [27], this result is broadly consistent with the claim that '[A]daptive processes characteristically improve exploitation *faster* than exploration. *These advantages of exploitation cumulate*. Each increase in competence at an activity increases the likelihood of rewards for engaging in that activity, thereby further increasing the competence and the likelihood' ([27], p. 73. Emphasis added). We could not find a more accurate description of our model of structural inertia as a dynamic positive feedback process, resulting both in the progressive cumulation of organisational competencies, as well as an improved ability to reproduce past behaviour.

Building on this insight, a second conclusion supported by our models is that inertia does not have the exclusive effect of making organisational structures less responsive to *external* stimuli [43]. As the level of structural inertia increases, the internal pressure for change obviously increases making change attempts more likely. But as inertia increases, the actual threshold for change also increases making change attempts less likely to succeed, at least for a given level of managerial effort. Hence inertia is a relative concepts not only because it implies a comparative assessment of the speed of organisational change and the speed of environmental change, but also—and perhaps mainly—because actual change depends on the *internal dynamics* of change attempts, and levels efforts needed to mobilise resources.

Because inertia acts as a multiplier of the threshold for change, as inertia decreases, for example, because the organisation is undergoing major transformations, the threshold for change decreases making future change more likely. This result is consistent with empirical evidence produced by studies of organisational mortality and change that have found that the probability of organisational change increases with the number of prior changes of the same type because processes or repetitive inertia operate both on stasis and change [11, 28]. For example, conditional on their age, Finnish newspaper organisations that changed the content and frequency of their publication at any time during the period 1771–1963 were shown to be more likely to experience similar types of change events again in the future [11].

Thirdly, alternative assumptions about managerial attitudes toward the value of experience have far-reaching implications for the dynamics of structural inertia and competence building in organizations, processes known to play a critical role in the evolution of organisational communities [38]. The results of the simulation experiments that we reported imply the existence of an 'ideal' level of resistance to change that allows organisations to build new resources and develop novel competencies, while simultaneously limiting fluctuations in the level of reliability, and reducing the rate of obsolescence of existing competencies. This conclusion is broadly consistent with current results in the area of organisational learning according to which organisations face an inescapable trade-off between processes of exploitation of old certainties, and processes of exploration of new possibilities [27]. According to our models, organisations in which the pressure for change builds up relatively fast as a consequence of deliberate managerial actions aimed at keeping the level of inertia low, do not find change particularly problematic because as inertia decreases the threshold for change decreases, and future change becomes more likely. However, while short-term pressures to meet performance expectations keep inertia low, they also tend to lock the organisation into a situation in which core competencies are hard to build and preserve because change generates more change. We believe that this result could provide a starting point for improving the quality of the theoretical debate on organisational change because it does not imply or assume that organisations are monolithically 'inert' or infinitely 'plastic.' Rather, this result clearly suggests that an optimal level of resistance to change exists below and above which organisational performance *can* be improved by stabilising existing routines or—as the case may be—disrupt them.

At the current stage our modelling efforts suffer from two main sets of limitations. The first is related to the fact that we presented a 'model of a model,' rather than a model of a specific organisational situation, or an empirically defined organisational problem. As a consequence the model reflects and in a way, accentuates the simplification of the underlying theoretical narrative and at no point we pursue the objective of improving its realism. A common criticism of 'models of models,' that is of more or less rational reconstructions of theoretical narratives, is that they do not so much reproduce the original theory as they reinvent it. This poses delicate problems of model validation [57, 58].

Clearly, many questions remain about the extent to which this problem is specific to system dynamics models, or—as we tend to believe—this represents a rather more general problem of interpretation of complex mental models [23, 59, 60]. In this respect, the main difference between models of theories and models of concrete processes seems to have less to do with the specific validation method that is appropriate, and more to do with the sources of information that trigger the model building exercise (informal—but 'locally informed'—mental models of 'managers' in the case of concrete processes, and formal—typically 'global' or structural but less detailed—mental models of 'theorists' in the case of theories).

A related problem typical of this kind of 'second order models' is that many elements of model specification may look arbitrary because organisational theories tend not to be developed in explicit dynamic terms and rarely specify exact functional forms that conceptual associations among variables ought to assume (i.e. they tend to lack a clear reference mode) [57].

In the analysis of real-world systems this problem is often circumvented by extracting patterns from historical data. In models of theories this solution is not readily available and the analyst is left with the task of extracting information on exactly how the variables are linked by interpreting theoretical narratives often expressed in natural language [57, 59]. The modelling framework that we adopted does not solve this problem, but graphic converters allow to test a wide range of possible functional relationships that may exist among high-level constructs like, for example, 'organisational size' and 'inertia,' which according to the theory are linked by a monotonically increasing function and explore their implications for the robustness of the theory. A detailed analysis of the sensitivity of the structural inertia model to alternative assumptions was far beyond the scope of the present study in which we concentrated on establishing a structured context within which issues of sensitivity and robustness can be addressed in the future. As we mentioned in the paper however, this problem does not have a direct empirical solution, although assumptions about specific functional forms have far reaching model specification implications in empirical research.

The second set of limitations—not entirely independent from the first—concerns issues of model validation, that is the assessment of the extent to which the range of dynamic behaviours produced by the model is consistent with what we know about actual organisations. Obviously, 'what we know' may take a variety of different forms including—but not necessarily limited to—numerical statistics. Accordingly there are several approaches to the validation of simulation models [61]. When modelling empirically observed processes, the problem of model validation can be addressed by analysing the extent to which the dynamic behaviour of the model reproduces history. Leaving aside questions about the adequacy of this intuitive and generally accepted way of validating simulation models, the theoretical nature of the underlying constructs prevented us to validate our models by direct comparison with history. Rather we took a 'link-by-link' approach to model validation by examining the conceptual arguments behind individual connections among variables. Hence, although our model is in broad qualitative agreement with the predictions made by ecological theories of organisational change, we cannot claim that were able to reproduce specific historical processes of organisational survival and transformation. More work and much bigger models are needed before we can extend the basic feed-back representation of the theory of structural inertia presented in this paper to include elements of realism grounded in a detailed understanding of specific organisational situations. This is likely to be the future direction that our research will take as we continue to explore new ways of designing models capable of capturing and representing the full dynamics implied by complex theoretical narratives about processes of organizational change.

Appendix: Model Equations and Documentation

Note that in a number of formulations below a time constant of 1 is assumed, but not made explicit in the model, to avoid 'cluttering' the model unnecessary with variables that have no influence (as they have the value of 1). In these cases the dimension is given as dimensionless/time. The equations below are in Powersim® format.

Due to the discrete nature of some of the rates in the model, the results presented will change when DT changes (DT can be interpreted as the organisational monitoring period). The results in this paper were obtained with DT = 0.125.

	Experience(t) = Experience(*t* – *dt*) – *dt** Decrease_in_Experience + *dt** Increase_in_Experience
	{Dimensionless. The accumulation of experience in the organisation}
init	Experience = 0
	{Dimensionless. Initial experience}
	Inertia *(t)* = Inertia(*t* – *dt*) – *dt** Decrease_in_Inertia + *dt** Increase_in_Inertia
	{Dimensionless. The accumulation of inertia in the organisation}
init	Inertia = 1
	{Dimensionless. Initial inertia in the organisation}
	Pressure_for_Change *(t)* = Pressure_for_Change (*t* – *dt*) – *dt** Decrease_in_Pressure_for_Change + *dt** Increased_Pres_F_Chang
	{Dimensionless. The accumulation of pressure for change in the organisation}

(*continued*)

(continued)

init	Pressure_for_Change = 0
	{Dimensionless. Initial pressure for change}
	Reliability *(t)* = Reliability (*t* − *dt*) − *dt** Decrease_in_Reliability + *dt** Increase_in_Reliability
	{Dimensionless. Accumulation of reliability in the organisation}
init	Reliability = 1
	{Dimensionless. Initial reliability of the organisation}
	Size *(t)* = Size (*t* − *dt*) − *dt** Decrease_in_Size + *dt** Increase_in_Size
	{Dimensionless. Size of the organisation}
init	Size = 10
	{Dimensionless. Initial size of the organisation}
	Decrease_in_Pressure_for_Change = IF(Change_ Attempt > 0, Effect_of_ Change* Pressure_for_Change, 0)
	{Dimensionless/ Time, The decrease in pressure for change in the organisation–Hidden time constant of 1}
	Decrease_in_Experience = IF (Change_Attempt > 0.1, 3.8* Experience, 0)
	{Dimensionless/Time. Decrease in experience, 3.8 is a scaling parameter which depends on the integration method, DT and how much experience can be lost in one organizational change organisation—Hidden time constant of 1}
	Decrease_in_Inertia = IF (Change_Attempt > 0, Inertia * Effect_of_ Change_on_Inertia, 0)
	{Dimensionless/Time, 0 is a parameter which determine the size of a change attempt that has to take place before inertia decrease organization—Hidden time constant of 1}
	Decrease_in_Reliability = IF (Change_Attempt > 0.5, Reliability, 0)
	{Dimensionless/Time. 0.5 is a parameter which determine the size of a change attempt that has to take place before reliability decreases organization—Hidden time constant of 1}
	Decrease_in_Size = Size *0
	{Dimensionless/Time. The model assumes that there is no direct decrease in size-organisation—Hidden time constant of 1}
	Increase_in_Reliability = (1/Variability) − Reliability
	{Dimensionless/Time organisation–Hidden time constant of 1}
	Increase_in_Size = Size * Age_Effect_on_Size
	{Dimensionless/Time organization—Hidden time variable Of 1}
	Increase_in_Inertia = Inertia * Exp_Eff_on_Inertia * Size_Eff_on_ Inertia + 0.05
	{Dimensionless/Time. 0.05 is assumed to be the steady accumulation of inertia that takes place in organizations—organization—Hidden time constant of 1}
	Increased_in_Pres_F_Chang = Expected_Reliability − Reliability
	{Dimensionless/Time. Increase in Pressure for Change organization—Hidden time constant of 1}
	Actual_Threshold = Multiplier_of_Threshold * Base_Threshold

(*continued*)

(continued)

{Dimensionless}
Age = TIME
{Dimensionless, Age is equal to time in the model, as the organisation was created at time 0}
Age_Effect_on_Size = GRAPH(Age,0,3,[0, 0.171, 0.199, 0.183, 0.151, 0.097, 0.062, 0.041, 0.022, 0.009, 0.001 'Min: –0.1; Max: 0.2'])
{Dimensionless. The relationship between age and size}
Experience_Effect_on_Variability = GRAPH(Experience, 0, 5, [1, 0.79, 0.67, 0.59, 0.54, 0.51, 0.48, 0.46, 0.43, 0.42, 0.41 'Min: 0; Max: 1'])
{Dimensionless. The relationship between experience and variability}
Change_Attempts = IF (Pressure_for_Change > Actual_Threshold, 1, 0)
{Dimensionless}
Effect_of_Change = NORMAL(1.6, 2, 27363)
{Dimensionless. The stochastic effect of change given by a normal distribution}
Effect_of_Change_on_Inertia = NORMAL(3.2, 2, 27363)
{Dimensionless. The stochastic effect of change on inertia given by a normal distribution}
Exp_Eff_on_Inertia = GRAPH(Experience 0, 3, [0, 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.1 'Min: –0.2; Max: 0.2'])
{Dimensionless. The relationship between experience and inertia}
Expected_Reliability = Reliability + Reliability * Trend_in_Reliability + 0.05 * Reliability
{Dimensionless. 0.05 is the baseline improvement to be expected by the management/shareholders per time unit}
Multiplier_of_Threshold = GRAPH(Inertia, 0, 0.3, [0.739, 0.767, 0.809, 0.896, 1.03, 1.125, 1.202, 1.261, 1.286, 1.289, 1.293 'Min: 0.7; Max: 1.5'])
{Dimensionless. The relationship between inertia and threshold}
Size_Eff_on_Inertia = GRAPH(Size, 0, 200, [0.886, 0.991, 1.025, 1.06, 1.093, 1.112, 1.133, 1.147, 1.167, 1.182, 1.193 'Min: 0.8; Max: 1.2'])
{Dimensionless. The relationship between size and inertia}
Size_Effect_on_Variability = GRAPH(Size, 0, 500, [0.99, 0.89, 0.82, 0.76, 0.71, 0.68, 0.66, 0.64, 0.62, 0.61, 0.61 'Min: 0; Max: 1'])
{Dimensionless. The relationship between size and variability}
Trend_in_Reliability = TREND(Reliability, 3, 1)
{Dimensionless. Trend is based on a 3rd order smoothing of reliability}
Variability = Base_Variability * Size_Effect_on_Variability * Age_Effect_on_Variability
{Dimensionless}
Increase_in_Experience = 1
{Dimensionless. In this model we assume that experience accumulates with a constant rate organisation—Hidden time variable of 1}
Base_Threshold = 2
{Dimensionless}

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