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# Causality and Endogenous Structural Change in Economics and History

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Pre-print version, August 23rd 2015.

**Abstract** There is traditionally a division of labor between economics and economic history, the task of economic history being that of studying the evolving constraints of economic mechanisms. Recent theorizing on endogenous structural change challenges this view: if structural change is endogenous to economic mechanisms, any strict division of labor between causal analysis and structural analysis breaks down. Rather such views call for an integration of causal and structural analysis. This paper looks for such a methodology, noting especially the contributions made by two Swedish economists, Johan Åkerman (1896-1982) and Erik Dahmén (1916-2005). With evolutionary, Marxian, Hayekian and critical realist contributions, the paper examines notions of endogenous structural change with the aim of expounding how the notion can be thought in terms of underlying mechanisms to aid such structural analysis. The findings of endogenous mechanisms underlying structural change are crystallized into a mathematical model and a simple methodological framework.

**Keywords** endogenous structural change, causality, economic methodology, emergence

## 1 Introduction

Causal inference in historical and complex systems is one of the core methodological issues of the social sciences. The problem is well-known: what are we to make

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For comments on previous drafts I wish to thank Lawrence Boland, Lennart Erixon, Magnus Granberg, Erik Green, Jonas Ljungberg, Anders Ögren and participants at the XIX Annual Conference of the European Society for the History of Economic Thought in Rome, Italy and the History of Economics Society's Annual Conference 2015 in East Lansing, Michigan. All remaining errors are my own.

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of causality when the study object does not allow us to isolate causes and effects in controlled and repeatable experiments? The main problem facing the social scientist is to disentangle causal relations from the web of relations that make up complex systems. Most methodological contributions to these issues explicitly or implicitly point towards notions of *structure* and stability as being integral to isolate and delineate causal relations in complex systems. In open complex systems, causal mechanisms presuppose structural stability, the *caeteris paribus* or some set of auxiliary assumptions. Accordingly, empirical approaches to causality tacitly or explicitly presuppose structural stability that allows recurrent causal relations to be expressed. This is commonly the analytical function that the notion of structure obtains in economics, history and other disciplines in the social sciences. Structure is then a reified fact, the theatre on which agents play their roles.

With such a notion it is not surprising that the conjoint study of structural change, i.e. changes in institutions, technology, production etc., are typically not directly involved in causal analysis. As it were, one cannot both hold things constant and analyze their change. Rather, as regards economics, a commonly held view is that there is a division of labor between economics and economic history. If economics is the study of general laws and mechanisms – whether in theoretical models or econometric applications - the role of economic history is to provide historical accounts and perhaps even theories of structural stability (periodizations) and structural change. Or, as Douglass North phrased it, "It certainly should be the distinctive province of the economic historian to theorize about the evolution of constraints that determine the structure of economies", even adding that "until we do undertake this task, I see no reason for economists to take us seriously" (North, 1978, p. 78). In this view, structural analysis is thus a complementary facet of causal analysis, enabling an understanding of the boundaries of causal mechanisms and general laws in economics (as it is elsewhere).

If we are to subscribe to the view that structural analysis is a necessary complement to causal analysis, we are however confronted with a second issue: What is in fact meant with the ubiquitous word "structure" and how do structures relate to choices made by economic agents? As the intellectual history of the notion reveals, thinking "structure" is fraught with several issues, one of which concerns the relation between agency and structure – or the micro-macro problem. A related issue concerns the endogeneity (or exogeneity) of structural change to economic mechanisms. Two polar positions on structure are traditionally recognized. In a reductionist view, "structures" are short-hand notions to denote an aggregate of some properties, choices or behavior of individuals, which exhibits some degree of inertia. Conversely, in realist views, structures are ontologically emergent viz. irreducible in principle to lower-level phenomena.

Both these views are problematic. If structure is explicable in terms of agency or if structure determines agency, structure and agency are merely points in the same process and structural change is rendered exogenous by definition to the system of thought or the mechanism under consideration. Is structural change, for instance changes in technology or institutions, really exogenous to economic behavior? This issue has encouraged attempts to re-invent the notion of structure and the relation between agency and structure. In economics, especially in recent years, several contributions, e.g. in the economics of complexity and evolutionary economics (see e.g. Arthur et al, 1997; Antonelli et al, 2008), post-keynesian economics (Pasinetti, 1983) and in contributions to institutional theory (see Greif and Laitin, 2004) have

sought to explain the emergence of structure and structural change as a result of economic behavior, while still accounting for an influence of macro-structure on economic or other choices. Thus structures are considered to constrain or support agency while at the same time evolving as a result of economic behavior.

There are however two challenges to such notions of endogenous structural change. Apparently, such a notion has radical corollaries to our view of the mutual independence of causal and structural analysis: if structural change is endogenous to economic mechanisms, any strict division of labor between causal analysis and structural analysis, between economics and economic history, breaks down. Structural change becomes as much an object of inquiry into economic behavior and economic mechanisms as it is of exogenous driving forces. Thus, as I will argue, it appears that this view requires causal and structural analysis to be integrated. Not only is structural analysis then a prerequisite for causal analysis, but the question becomes how to empirically observe and analyse structural stability and change.

A second intellectual challenge is that there appears to be something self-defeating about a notion of endogenous structural change. Is it not an oxymoron of sorts? How can structures change as a result of factors endogenous to them? Or going deeply into matters: how can there be endogenous novelty in a theoretical system, as with Wittgenstein "there can *never* be surprises in logic" (Wittgenstein, 2001 [1922], 6.125)?

In light of these issues, the current paper aims to do two things. First, this paper studies the points of contact between economic and economic historical analysis through a study of notions of causality, structure and structural change. How could the analysis of causal mechanisms be integrated with a conjoint study of changes in underlying structures? The paper begins therefore with discussing the issue of how causal analysis and structural analysis can be integrated. This section especially notes and makes use of the critical and constructive contributions to structural analysis made by two Swedish economists, Johan Åkerman (1896-1982) and Erik Dahmén (1916-2005), who have played a salient role in Swedish economic history as a discipline (see e.g. Schön, 2010). Being one of the earliest Swedish institutionalists alongside Gunnar Myrdahl, Johan Åkerman's project was largely that of introducing history into economics, thus providing a bridge between economics and economic history. He criticized notions of structure in economic and historical analysis for providing insufficient ground for proper economic causal analysis and developed a methodology for the empirical analysis of structure and structural change. Erik Dahmén further developed Åkerman's structural analysis towards a notion of endogenous structural change, especially through his concept of development blocks (Dahmén, 1991 [1942], 1950; Schön, 1991, 2010; Erixon, 2011).

Second, the paper examines the notion of endogenous structural change with the aim of expounding how the notion is thought and *can be* thought in terms of underlying mechanisms in order to aid empirical analysis of evolving structures. In section 3, I deal with the question of how notions of endogenous structural change can be thought, through a brief review of recent theorizing on the notions of structure and structural change in the economics of complexity, evolutionary, Hayekian, critical realist and Marxian theories. The findings are crystallized into a simple mathematical model of endogenous structural change. The paper concludes by summarizing the discussion and a reflection on empirical study of the evolution of economic and social structures.

## 2 Towards an integration of causal and structural analysis

It could seem a hopeless task to try to make sense of two so ubiquitous and commonsensical words as are causality and structure. Yet, these words open up worlds: what meaning one puts in them tells us of underlying ontologies or epistemologies about how we perceive inter-relations between phenomena. More importantly, these notions are interrelated. In this section, I will try argue that ontological positions on causality in mainstream economic theory have engendered certain approaches towards structural analysis. Essentially, there are two possible ones: either structural stability is implicitly assumed as a prerequisite of the expression of causal mechanisms but ultimately "exogenized", or it is explicitly incorporated as a facet of causal mechanisms, thus making the causal analysis inseparable from structural analysis.

### 2.1 Causality and structure in closed systems

It is well known that the dominant notions of causality finds its intellectual roots in Hume's empiricist and atomist philosophy. Causality is understood as the constant conjunction of a cause  $A$  with the effect  $B$ , where the cause is antecedent to the effect. Hume's epistemological view of causation was rooted in an ontological atomism, attested in "All events seem entirely loose and separate" (Hume, 2011 [1748], Section II). Thus, Hume denounced the possibility of direct observation of certain relations between objects: "The simple view of any two objects or actions, however they are related, can never give us any idea of power or of a connection between them" (Hume, 2012 [1738]). Causality is thus always, at best, a hypothesis, an observation of repeated occurrence of a cause  $A$  with an effect  $B$ .

It is possible to argue (see e.g. Bhaskar, 2008 [1975], Lawson, 1997 and Moneta, 2005) that Humean notions of causality have primarily induced empirical strategies that center on reproducing *closed* systems or observing constant conjunctions. As noted by Hoover (2001, 2008) and Moneta (2005), the probabilistic approach to causality is a canonical econometric successor of the Humean view. Granger's (1969) hugely influential concept of causality relies on a simple notion of causality, namely that  $A$  causes  $B$  if  $P(B|A) > P(B)$  and  $A$  occurs before  $B$ . Clearly, this is a generalization of Hume's requirements of constant conjunctions of events and the antecedence of cause to the effect, which could be restated as " $A$  causes  $B$  if  $P(B|A) = 1, P(B) = 0$  and  $A$  occurs before  $B$ ". An extension of this definition was given by Granger (1980), according to which what is now commonly called Granger causality holds between a variable  $X$  and  $Y$  if in the equation  $Y_t = \sum_k^L (\beta_{t-k} Y_{t-k} + \beta_{t-k} X_{t-k}) + \epsilon_t$ , with lag length  $L$ ,  $\beta_{t-k} \neq 0$  for some  $k$ . Thus,  $X$  Granger causes  $Y$  if, controlling for the previous information on  $Y$ ,  $X$  has a (positive or negative) effect.

Another attractive methodological alternative lies in natural experiments: experiments where causes and effects can be isolated, by "nature" giving two cases similar in all aspects but the fact that one has been treated, the other not.<sup>1</sup> A

<sup>1</sup> An archetypal example might be West and East Germany, giving a test of the effects of their respective economic systems during the postwar period. Natural experiments must however be random, double-blind and free of omitted variable bias, which imposes a problem of finding good natural experiments. In comparing the impact of the economic systems of West and East

similar alternative, pioneered by P.G. Wright in 1928, is the instrumental variable approach that has become widespread in recent years (see Angrist and Krueger, 2001 for a review).<sup>2</sup>

These methodological approaches to causal analysis appear to presuppose notions of structure (stability) as exogenous to economic mechanisms. There are two ways in which structure is introduced in neoclassical economics:

- as *caeteris paribus*. An exogenous state of affairs unaffected by the causal mechanisms under study, or a set of assumptions of other things being equal that in practice imply ignoring "the element of time".<sup>3</sup>
- as *equilibrium*. The endogenous outcome of the causal mechanism under consideration, which however upon being attained can never be superseded by factors endogenous to the causal mechanism under consideration.

It is on these terms that the job of the economic historian, the study of the "evolution of constraints" can be separated from causal analysis proper. However, these notions clearly run counter to the idea of endogenous structural change. Some of the more familiar criticisms towards these approaches have been advanced by Nicholas Kaldor (Kaldor, 1972) and Joan Robinson (1962, 1980). Kaldor remarked that "The very notion of 'general equilibrium' carries the implication that it is legitimate to assume that the operation of economic forces is constrained by a set of exogenous variables which are 'given' from the outside and stable over time" and that in such a framework "Continuous economic change [...] can only be conceived as some kind of 'moving equilibrium' through the postulate of an autonomous (and unexplained) time-rate of change in the exogenous variables of a kind that is consistent with 'continuous equilibrium' through time-such as a given rate of shift per unit of time in the production function of the so-called 'Harrod-neutral' type or in the supply of resources: an exogenous rate of growth in the labour force and/or in the rate of increase in 'capital' [...]" (Kaldor, 1972, p. 1244). Less familiar, but in a similar fashion, Johan Åkerman (see below) argued that as a concept for structural analysis in historical settings, equilibrium or "l'ordre naturel" was directly

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Germany on their respective growth rates (or similar), their division must be ascertained to be random, and there cannot be latent variables such as the industrial conglomerate in the Ruhr area may well be).

<sup>2</sup> The approach is aimed to resolve, *inter alia*, the problems of reverse causality (viz. endogeneity) and omitted variables by finding exogenous instruments, i.e. variables that are strongly correlated with an independent variable but not with the dependent variable. The approach is carried out by first regressing an independent variable  $X$  on a suitable instrumental variable  $Z$  that is plausibly exogenous and uncorrelated with all other independent variables. Then the effect of  $Z$  on the dependent variable  $Y$  can be estimated. The approach is capable of isolating the effect of the hypothesized dependent variable regardless of whether the model has omitted variables in general. However, the omitted variables *must not* be correlated with the instrument.

<sup>3</sup> As was expressed by Alfred Marshall, the "element of time is a chief cause of those difficulties in economic investigations which make it necessary for man with his limited powers to go step by step; breaking up a complex question, studying one bit at a time, and at last combining his partial solutions into a more or less complete solution of the whole riddle. In breaking it up, he segregates those disturbing causes, whose wanderings happen to be inconvenient, for the time in a pound called *Caeteris Paribus*. The study of some group of tendencies is isolated by the assumption other things being equal: the existence of other tendencies is not denied, but their disturbing effect is neglected for a time. The more the issue is thus narrowed, the more exactly can it be handled: but also the less closely does it correspond to real life" (Marshall, 2009, p. 180).

unsuitable, a fiction, in which "there is no place for systematic structural change", nor endogenous systematic variations such as the business cycles (Åkerman, 1939, pp. 263-264; translation of quotes by JT). Thus, upon being attained equilibrium can never be superseded by factors endogenous to the causal mechanism under consideration, rather they must stem from the exogenous realm.

Clearly, if changes in production, technologies and institutions are endogenous to economic mechanisms, one must look for ways of transcending the division of labor between causal and structural analysis. This would also encourage rethinking both approaches to the observation of causal mechanisms and the notion of structure.

## 2.2 Causal ontologies in open systems

There are causal ontologies that carry some way towards such a transcendence. Against Humean atomism, there is a commonly repeated intuition among those who would point to the importance of context, history and structure, to say that events, agents and variables do not exist in isolation. Some notions of causality attempt to explicitly deal with the complexity of open systems (Bhaskar, 2008 [1975]; Lawson, 1997), encouraging the conjoint study of economic structures *head on* in order to understand the conditions of validity of the causal mechanism. Such onto-epistemologies imply that, rather than the atom, the fundamental onto-epistemological unit is the relation between phenomena. Relations thus *precede* the *relata*, implying that the *relata* emerge through the process in which they become related. This means that events and processes are always already immersed in spatio-temporal causal structures that govern the state of affairs.

One of the main approaches along such lines, Bhaskar's critical realist project emerged as a critique both of Hume's classical empiricism as well as Kant's transcendental idealism, both of which seriously question our ability to observe causal connections between events. On the contrary, Bhaskar is an example of ontological realism about causality. Bhaskar (2008 [1975]) in particular argues that the constant conjunction of events is neither a sufficient nor a necessary condition for scientific or causal laws. Instead, Bhaskar argues that in experimental activity, the researcher is a causal agent of a sequence of events, but not of the causal law that the experiment allows him or her to identify. Causal laws must, for science to be possible, exist independently of scientific activity. In this view, the object of scientific research is knowledge of *generative mechanisms*, viz. *causal structures* that are irreducible to the phenomena that they generate: "The world consists of mechanisms not events. Such mechanisms combine to generate the flux of phenomena that constitute the actual states and happenings of the world" (Bhaskar, 2008 [1975], p. 47). However, "it is only under closed conditions that there will be a one-to-one relationship between the causal law and the sequence of events" (Bhaskar, 2008 [1975], p. 46). In open systems, generative mechanisms may be at work, but counteracted by other generative mechanisms. This forces researchers to reconsider causality as, not a constant conjunction of events, but rather, generative mechanisms, that may, or may not, be activated or manifested. To Bhaskar, the task becomes to discover generative mechanisms through analysis of structures.

Lawson (1989) has argued that Keynes view and macroeconomic approaches express such a realist concern about causality because of the implausibility of the

atomist view and since societies and economies are typically open systems. Similarly, the structuralist approach in econometrics implied the study of systems of interdependent variables, attacking the intriguing question of what becomes of causality in systems where all variables are interdependent (Haavelmo, 1944; Simon, 1953; Simon and Rescher, 1966). In face of the puzzle of how to identify stable relations in interdependent systems, Haavelmo (1944) argued for distinguishing autonomous relations, i.e. relations which are invariant under different circumstances. A particular system of behavioristic relations and institutional restrictions on choices defined a particular *structure*, "a theoretical set of possible simultaneous sets of value or sets of time series for the economic variables" (Haavelmo, 1944, p. 28). Thus, if there is a certain relation that is invariant with respect to a set of different structures one may say that the relation is autonomous with respect to a class of structures. While Haavelmo considered the task of economics to be to find out of such autonomous relations<sup>4</sup>, he also argued that when facing exogenous changes that affect the autonomous relations, if "we cannot clear the data of [...] 'other influences,' we have to try to introduce these influences in the theory, in order to bring about more agreement between theory and facts" (Haavelmo, 1944, p. 18). Haavelmo did not discuss how structural change could be included in models. However, this passage points towards an explicit structural analysis as an activity conjoint to the search for generic autonomous relations among variables.

### 2.3 The case for structural analysis

The realist perspectives on causality carry some way towards merging causal with structural analysis. However, if we accept that not only structure, but also structural change should be studied *head on* as a part of causal analysis, we run into an opposite problem: how can structures and structural change be studied empirically as a facet of economic historical analysis? The main issues at hand are then:

- How can the divide between causal analysis and the study of structural change be bridged?
- What types of endogenous mechanisms underlie structural change and stability and how can they be studied empirically?

I will approach these questions in sections 2.4 and 2.5, by introducing and reviewing two examples of empirical approaches that integrate causal and structural analysis, pointing towards the study of structural change as endogenous to economic mechanisms. These are Johan Åkerman's "causal analytical" notion of structure and Erik Dahmén's notion of "development blocks". Like many others with an institutionalist inclination, both Åkerman and Dahmén emphasized not only the study of structural stability, but structural *change* as an integral part of causal analysis. What is rare about these frameworks is however that they are examples of theoretical and methodological attempts to transcend the division of labor between economics and economic history, while also being focused on empirical application in economics and economic history. Though their empirical work was focused on economic development and industrial transformation, in reviewing

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<sup>4</sup> "The principal task of economic theory is to establish such relations as might be expected to possess as high a degree of autonomy as possible" (Haavelmo, 1944, p. 29).

these frameworks, I hope also to indicate what is unique and generalizable beyond economic applications in their methodologies.

#### 2.4 Causal structural analysis. The example of Åkerman's economic methodology

Inspired by Thorstein Veblen, Joseph Schumpeter and Friedrich von Hayek, Åkerman was next to Gunnar Myrdahl one of the earliest and most influential Swedish institutionalists (see Mjøset 1994, Pålsson Syll 1997, Carlson 1999 and Erixon 2011). Åkerman can be placed fairly close to the critical realist views as concerns their basic outlook of structure and society, harboring a critical attitude towards "atomism", Åkerman being dubbed as "holist" (Nyblén, 1949). This implied that he saw as a central aspect of economic theory as understanding the shifting material and institutional setting in which economic processes take place. Delimiting structures and understanding the driving forces of structural change was the purpose of Åkerman's structural analysis. Åkerman distinguished sharply between "models of calculation", rationalisations of the calculations of subjects, and a "causal analysis" aiming to reconstruct the total economic process and to understand and predict its development (Åkerman, 1939, p. 9). In Åkerman's view, both causal analysis and models of calculation are temporally localized, i.e. only valid as long as a particular economic structures is at hand, which for Åkerman motivated structural analysis.

A basic definition of structure was given by Åkerman at one occasion as a "within given temporal boundaries, the structural boundaries, rather stable economic mechanism" (Åkerman, 1949, p. 1; translation by JT). This immediately points at a venue for empirical analysis. Structural boundaries, i.e. the temporal boundaries of certain stable economic mechanisms, could according to Åkerman be observed through the empirical analysis of the trends and turning points of "structural indicators", such as the the distribution of income and credit on the private and public sector and the distribution of income on industries (Åkerman, 1939, 1949).<sup>5</sup>

However, against other static, dynamic or "purely historical" concepts of structure, Åkerman stressed a causal analytical concept of structure. To explain this concept, Åkerman likened economic analysis to an analysis of a game of pool. Given a set of initial conditions, one may calculate the alternate ways a set of billiard balls came to end up in given positions. This is an astructural analysis. Asking instead what causal factors that determined the direction and force of the strike chosen, takes the analysis outside of the pool table and is analogous to a structural analysis. Structures determine the dominating causal factors (Åkerman, 1939, p. 265). This notion of structure also necessitates an understanding of the causes of structural change and an incorporation of this structural analysis into the analysis of economic theory:

"To formulate an economic theory, which suits a certain temporally and spatially localized reality, one must thus know the structural framework in which

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<sup>5</sup> Several other indicators have later been used by economic historians as structural indicators, e.g. the ratio of domestic investments to GDP and the ratio of Paasche to Laspeyres price indices, known as the 'Gerschenkron effect' on the basis of which periods of structural stability have been distinguished. See e.g Schön (1998, 2010).



the activity takes place. But this means, that one knows something of the structural *changes* and the causal connections that operate in this sphere. Knowledge of the economic principles are thus dependent on knowledge of structural changes; the questions, which are described in models of calculation stand in a relation of interdependence to the process described in causal analysis. The logical models of calculation rest on a foundation that is continuously changing; it is not sufficient to know the foundation in one particular case - one must also research the laws of structural change. The concept of economic structure therefore can never denote anything else but a relativistic reality: the position of a certain structure in relation to previous and subsequent structures, by which the concept becomes an instrument in the search of the forces that govern structural changes" (Åkerman, 1939, p. 262; translation by JT).

I should like to emphasize how, as the lengthy quote suggests, Åkerman's project implied the *mutual dependency* between structural analysis and causal analysis. The calculation models and causal analysis crucially implied a structural determination, a "spatio-temporally localized reality", while at the same time the structural analysis has a decidedly relativistic and therefore causal core. Structural analysis thus also means to seek an understanding of the driving forces of structural change. *In nuce*, causal structural analysis consists not only of a description of causal mechanisms but also the evolution of causal mechanisms through analysis of structural change and its driving forces.

Åkerman (1944, pp. 27-28) clarified that such search for driving forces is a process, one is tempted to say an iterative process, in which *ostensibly closed systems* ("skenbart slutna sammanhang") are connected to forces exogenous to the particular mechanism (just as the analysis was moved outside of the pool table in the previous example), which in its turn forms a new ostensibly closed system whose structural changes can be understood by repeating the process.<sup>6</sup> Expressed otherwise: "The mechanism's open moment is the subject of causal analysis and one seeks to localize these to connect them with in relation to the mechanism exogenous driving forces, which in their turn stand in a temporally interdependent relationship" (Åkerman, 1944, p. 28, translation by JT, original emphasis).

Åkerman demonstrably understood causal analysis as finding *exogenous* driving forces, being entirely distinct from endogenous interdependence (Åkerman, 1960, p. 284-287). By beginning with a closed system, one could approach a wider picture of the driving forces of structural changes by researching the "open moment". *Prima facie*, this methodological understanding of causality is similar to Schumpeter's methodological outlook. The early Schumpeter stated: "When we succeed in finding a definite causal relation between two phenomena, our problem is solved if the one which plays the "causal" rôle is non-economic. We have then accomplished what we, as economists are capable of in the case in question, and we must give place to other disciplines. If, on the other hand, the causal factor is itself economic in nature, we must continue our explanatory efforts until we ground

<sup>6</sup> "The concept driving force becomes in causal analysis of fundamental importance. In this concept [...] lies a standpoint towards the nature of causality, to the connection between pure economic mechanism and exogenous factors. With the notion driving force the causal explanation is moved outside of the analyzed process, it is not sought in the factors', even less the concepts', logical interplay. The causal explanation is thus successively driven from one ostensibly closed system to another ostensibly closed system and from there to another ostensibly closed proces, etc." (Åkerman, 1944, pp. 27-28, translation by JT).

upon a non-economic bottom" (Schumpeter, 1911, pp. 4-5). However, by adding an "etcetera" to the causal analytical process (see footnote), Åkerman insinuated that the search for exogenous driving forces could in principle continue well beyond economic mechanisms, forming a new ostensibly closed system. Thus, it is through the successive incorporation of exogenous driving forces that structural change could be analyzed.

In his analysis of economic development of leading industrialized countries 1820-1940, Åkerman pointed out eight possible driving forces to structural change, e.g. technological development, population increases, the development of the credit system and the distribution of income. These factors were viewed as exogenous, but not exclusively. Rather Åkerman considered their status vis-à-vis the economic mechanism to vary over the course of (say) a business cycle. Thus Åkerman distinguished between "free" driving forces, *in statu nascendi* and "bounded" driving forces, those that have been active but "now crystallized in the current order" (Åkerman, 1944, p. 41, JTs translation). These bounded driving forces would with the 'structural heritage' from previous development form a new structure, while the actual process of structural change is the result of "contact and conflict between new, free, driving forces and the extant structure or institutions, such as these have emerged from the actions of previous driving forces" (Åkerman, 1944, p. 41, JTs translation).

In sum, structural analysis in Åkerman's approach thus involved two complementary modes of analysis, which I will refer to as *M1* and *M2*:

- M1*: the determination of structural boundaries, stable economic mechanisms, primarily through the analysis of structural indicators, and  
*M2*: the analysis of the driving forces of structural change.

## 2.5 Causal mechanisms in endogenous technological change. Dahmén's approach

The previous two points serve as apt starting points of an integration of causal and structural analysis. However, the structural analysis of Åkerman does not specify mechanisms whereby new structures emerge, are stabilized or transformed. The second question is thus posed in the domain of economic history: what mechanisms create, reproduce or transform structures? In his work on industrial transformation and structural change, Erik Dahmén continued and in some ways "dynamized" Åkerman's notion of structure, through his concept of development blocks (see below). Dahmén's work is characterized by a rich underlying ontology of conflict, complementarities and inertia. Dahmén operated with a fundamental notion of industrial transformation and structural change that had "its center somewhere between two extreme situations", a positive situation characterized by opportunities, and a negative situation characterized by declining demand and a "strongly felt necessity to adjust and adapt" (Dahmén, 1991a, p. 138). In this way, there was a conflict between new and old ways of doing things. In his doctoral dissertation, (Dahmén, 1950) coined the term 'transformation pressure' to describe the fundamental aspects of the industrial transformation process. A positive transformation pressure characterizes a situation dominated by opportunities, such as opportunities to increase production or advance or exploit new technologies. Conversely, a negative transformation pressure characterizes a situation dominated by declining profits or demand and a felt need for response (Dahmén, 1991a, 1993).

Dahmén's analysis of industrial transformation aimed to establish bridges between micro and macro. On the one hand, like Åkerman, Dahmén was critical of Keynesian macroanalyses. Macroanalyses without microfocus miss out on the variety of underlying microeconomic driving forces, leading to incorrect and even misleading pictures of the state of the economy, the so-called "fallacy of aggregative thinking" (Dahmén, 1991b, pp. 128-129). On the other hand both Åkerman and Dahmén were critical towards atomism, or methodological individualism, rather arguing for a symbiosis of micro-, structural and macroanalysis.

Dahmén's (1991 [1942]; 1950) major conceptual contribution of "development blocks" was a conceptual link between micro and macro that emphasized the formation of interdependent activities. The development block concept was an early theoretical contribution to the theory of technological systems, stressing the systemic character of innovation activity and technological change (for seminal later contributions see Rosenberg, 1969; Gille, 1978; Hughes, 1987; Bresnahan and Trajtenberg, 1995; Freeman and Louça, 2001; Lipsey et al, 2005). Development blocks are *complementary economic activities that are stimulated by innovations*. The central dynamics of a development block is provided by the fact that new technologies or innovations require investment and development efforts in other firms or industries: "A series of events in entrepreneurial activity, technical development (including innovations) where the different linkages [...] in one or another manifestable way have causal connections with each other or condition each other" (Dahmén, 1980, p. 50, translated by JT). As it were, innovations create *complementarities*, or dependencies between firms, technologies, industries or institutions. In this process obstacles and imbalances appear that require the alignment of the technological frontier in other fields, or new innovations that solve technological problems (cf Rosenberg, 1969; Hughes, 1983; discussed below). Development blocks are, put in a more involved manner, complementarities that appear sequentially as agents overcome obstacles or imbalances.<sup>7</sup> The Dahménian approach crucially also stresses the inertia present in aligning components of development blocks. The lack of complementary factors may as it were hamper the development of other factors. Dahmén discussed, for instance, the unprofitability of railways during the late 19th century that were unprofitable until complementary investments in the railway network had been carried out (Dahmén, 1991 [1942], p. 30). This relation was referred to as *imbalances* or "structural tensions" (Dahmén, 1950, p. 70-73; Dahmén, 1991 [1942]).

Thus, in Dahmén's ontology of structural change there are both positive and negative factors that provide impetus to industrial transformation and technological change. The notion of development blocks can be argued to represent a theory of endogenous structural change that links micro-behavior (entrepreneurial activity) to structural and macro-outcomes. Through sequences of complementarities and structural tensions, structures of economic relations were thus posited to evolve endogenously as a result of economic choices. While Dahmén did not formulate a theory of entrepreneurial activity as endogenous to economic mechanisms, in his later work (Dahmén, 1993), he briefly considered a notion of countermeasures to changes in economic conditions, somewhat similar to Joseph Schumpeter's notion

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<sup>7</sup> Dahmén described the notion of a development block as "a sequence of complementarities which by way of a series of structural tensions, i.e., disequilibria, may result in a balanced situation" (Dahmén, 1991a, p. 138).

of creative response (1947). Positive situations, characterized by new opportunities, would provide powerful incentives towards renewal and towards innovation as offensive countermeasures. Negative transformation pressure, for instance high input costs, could induce defensive countermeasures in cost reductions or organizational rationalization. Other types of negative transformation pressure could induce offensive countermeasures: "cases where innovations are induced by a destructive threat and thus would not otherwise have been forthcoming" (Dahmén, 1993, p. 23). These two driving forces were incentives towards transformation in firms, industries and in development blocks (see Taalbi 2014 for further discussion).

In sum, Dahmén took Åkerman's structural analysis further towards a notion of structural change in which economic development was itself a factor influencing industrial transformation, through pressures, opportunities, complementarities and structural tensions.

## 2.6 The Åkerman-Dahmén framework

In sum, Åkerman's structural analysis meant two things: first, observing structural stability and structural boundaries through analysis of structural indicators and second, the iterative search and incorporation of driving forces exogenous to the mechanism under study - the "ostensibly closed system" in order to understand structural change. While Åkerman's analysis may be argued to have approached but ultimately underplayed endogenous structural change, Dahmén's notion of development blocks contains seeds to a notion of structural and technological change in which the "free driving forces" are also codetermined within a given structure. In Dahmén's framework of development blocks he sought to explain the interdependencies in the process of economic development and technological change, studying both the emergence of new structures and sources of structural change. The underlying ontology makes space for both positive and negative driving forces of industrial transformation, and stresses both complementarities and imbalances in the evolution of development blocks. In terms of empirical enquiries, this points towards the study of positive and negative mechanisms that occasion agents to respond by innovation.

## 3 A notion of endogenous structural change

If the goal of structural analysis is the reconstruction of the total situation by the successive submission of exogenous mechanisms to causal analysis, Åkerman and especially Dahmén came a long way towards an understanding of structural change which is susceptible to the behavior of micro-agents. Though Dahmén's work contains an ontology of positive and negative interrelations between agents, he did not himself however present a fuller theory or account of the precise mechanisms that underlie endogenous structural change. Let us now pick up the thread of what is precisely meant with endogenous structural change and how it can be thought in terms of economic mechanisms. Phrased otherwise: how can one think structural change as arising within the frames of structure without being trapped in circular reasoning or tautology?

### 3.1 The debate on structure and agency in the social sciences

A lengthy discussion in the social sciences has concerned the relation between agency and structure, and it is in the attempts to solve this issue that perhaps the most fruitful notions of structure have emerged. Taking a broader perspective than economics, in old and recent work, the difference between reductionist and realist perspectives has tended to be reiterated in discussions on how structure is related to agency. The issue has to a large extent been dealing with how structures emerge to begin with, and the co-determination of emergent structures and agency, or if you will *mereology*, the relationship between the parts and the whole. *Emergence* in its the most encompassing sense, means that the complex interaction between parts may result in new phenomena at a higher level. The basic emergentist view can be summarized in that "The totality is not, as it were, a mere heap, but the whole is something besides the parts" (Aristotle *Met.* Book H, 1045a 8-10). The main divide in the view on emergence lies between those that view emergence as a bottom-up relation and nothing more, and those that consider it plausible that emergent structures *also* may be endowed with causal effects, implying downward causation. The first notion is completely compatible with methodological individualism. Economists from Mill (2011 [1843]), von Hayek (1945) to Arrow (1994) and Krugman (1996) writing more recently, argue that emergent phenomena arise from the complex interaction between individuals, while holding individualist ontologies whose dictum may be that of von Hayek: "neither aggregates nor averages do act upon one another, and it will never be possible to establish necessary connections of cause and effect between them as we can between individual phenomena, individual prices etc" (von Hayek, 2008 [1931], p. 200). Mill for instance acknowledged emergence, such as in chemistry or organic "bodies", while denying that human beings could form emergent entities.<sup>8</sup> This type of position means that emergence is an unintended result of intended actions among individuals that however never becomes endowed with proper causal powers, being ultimately explainable in terms of individuals or individual behavior. Arrow (1994, p. 3) for instance wrote: "It is clear that the individualist perspective does play an essential role in understanding social phenomena. Particularly striking is the *emergent* nature of social phenomena, which may be very far from the motives of the individual interactions. It is a salutary check on any theory of the economy or any other part of society that the explanations make sense on the basis of the individuals involved." To von Hayek (1937, 1945), on this individualist understanding, the free market was an example of spontaneous order, an order that emerges from unplanned, decentralized agency in which agents follow simple behavioral rules. These are all examples of bottom-up emergence, in which the emergent phenomenon is something besides its parts, but never obtains proper causal powers. The market is arguably not a force on its own, it is always reducible to the individual agents that partake in market transactions.

At the other side of the spectrum we find notions of emergence in which the emergent structures exhibit downward causation. It would appear that this runs counter to individualism, but as explained by Agassi (1975), individualism does

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<sup>8</sup> "Men are not, when brought together, converted into another kind of substance, with different properties [...]. Human beings in society have no properties but those which are derived from, and may be resolved into, the laws of the nature of individual man" (Mill, 2011 [1843], p. 425).

not necessarily denying the ontology of structures. "Institutional individualism" maintains that while only individuals can have aims and interests, institutional structures exist and affect individuals' decisions (Agassi, 1975). In other frameworks, downward causation appears either as "soutiens et obstacles" (Braudel, 1958), or as emergent structures determining the character of its parts. The latter is a type of emergence in which a global phenomenon emerges while at the same time giving rise to emergent conjugates, new properties among lower level phenomena (De Haan, 2006). This was the main thesis in Althusser and Balibar (1970), expressed in the principle of "structural causality", or *Darstellung*, what was considered Marx's key theoretical revolution, implying the efficacy of structures on its parts, that "the structure is immanent in its effects, a cause immanent in its effects in the Spinozist sense of the term, that the whole existence of the structure consists of its effects, in short that the structure, which is merely a specific combination of its peculiar elements, is nothing outside its effects" (Althusser and Balibar, 1970, p. 188). Marx's writings is replete with examples in which the capitalist mode of production, commodity exchange or the like is said to determine or have historically given rise to emergent conjugates: capitalists and workers, labor value of the individual goods partaking in commodity exchange, and so forth.

Combining the bottom-up emergence and top-down relations between structure and agency, we also find notions, especially in sociology, that attempt to formulate agency as afflicting structure *and vice versa*. There is however a paradox, logical contradiction even, in saying that agency 'causes' structure and that structure 'causes' agency (see Hulswit, 2006). Another interpretation can however be made when it is realized the historicity of structure, as famously expressed by Marx and Engels: "Men make their own history, but they do not make it just as they please; they do not make it under circumstances chosen by themselves, but under circumstances directly encountered, given and transmitted from the past" (Marx and Engels, 2001 [1885], p. 7). Inspired by Marx, but against more recent "dialectical" models of the relationship between agency and structure (people and society)<sup>9</sup>, Bhaskar (1998 [1979]) stressed this view as a solution to this problem. He underscored the deep *historicity* of structure: (social) structures are the historical products of human agency, being handed down to the present situation as the result of previous choices. Structure is not created *ex nihilo*, but agents

"reproduce or transform it. That is, if society is always already made, then any concrete human praxis, or, if you like, act of objectivation can only modify it; and the totality of such acts sustain or change it. [...] Society stands to individuals, then, as something that they never make, but that exists only in virtue of their activity" (Bhaskar, 1998 [1979], pp. 36-7).

Referring to Émile Durkheim, Bhaskar similarly stated that it is by their hindering or enabling effects, that structures can be observed: they "exist only in virtue of the activities they govern and cannot be empirically identified independently of them" (Bhaskar, 1998 [1979], p. 41). In his later work Bhaskar accordingly defined *holistic causality* (compare Althusser's structural causality) as the case when the totality causally determines the elements and the elements causally codetermine each other, and so determine or codetermine the whole (Bhaskar, 2008, p. 127).

<sup>9</sup> "People and society are not, I shall argue, related 'dialectically'. They do not constitute two moments of the same process." (Bhaskar, 1998 [1979])

In Bhaskar's view, emergent structures must be regarded *processes* in which the whole and parts are continuously differentiated. Not only the elements, but the meaning and content of the whole is thus changed, enriched. Structures are then emergent by virtue of them being reproduced or transformed by social agents and by their (real) historical influence *qua* hindering or enabling agency, determining and creating conjugate properties of its elements. In this way, structures are arguably causal factors as they stand independent of current choices whereas their evolution is reproduced or transcended by such choices.

### 3.2 Increasing returns, inertia and imbalances

Bhaskar's analysis is twice helpful for the aims of this study. It shows that endogenous structural change can be thought without tautology if we are willing to recognize that structure and agency are not two moments in a simultaneous process. It also provides tools that can help bring out what is general in Dahmén's mechanisms that underlie development blocks and structural change. Extending Bhaskar's suggestion somewhat, I suggest that there are three modes of analysis through which structural change can be explained: the emergence of structure (*M2a*), its reproduction (*M2b*), and transformation (*M2c*). Some mechanisms underlying these aspects of structural change are obvious in Dahmén's framework. Other, more precise mechanisms can also be found in the more recent literature.

Recognizing the presence of emergent structures in complex systems, economists and economic historians have during recent decades begun to study mechanisms that produce structure in complex systems. In particular, attention paid to the notion of increasing returns (Young, 1928; Kaldor, 1981) has been revealed to produce profound implications (Arthur et al, 1987; Arthur, 1989, 1990, 1994). In stark contrast to the standard economic scenario of decreasing returns which eventually attains a predictable single equilibrium point, increasing returns define multiple equilibria, among which the equilibrium situation eventually attained will be dependent on the path taken by the system. Increasing returns, positive feedback mechanisms and positive externalities (e.g. in economic or geographical networks) are the gist not only of crystallizing structures but of *path dependence*. Arthur (1989) discussed technological competition in which the returns to a technology increase with the rate as its adopted, noting these profound effects: the evolution of the system "takes on an evolutionary character, with a 'founder effect' mechanism akin to that in genetics. 'History' becomes important" (Arthur, 1989, p. 128). As the "economics of QWERTY" illustrates, the technology that eventually comes to dominate, needs not be the *a priori* best one (David, 1985), rather what counts is a first movers advantage and historical events.

The notion of complementarity, which defines the Dahménian "development blocks", could be defined in two movements. It is first of all closely linked to the notion of increasing returns. A relation of complementarity may be understood as a positive interdependence between different factors, for instance firms, industries or factors of production, in which the combination of parts increases the returns or value of both parts. Thus, following Stieglitz and Heine (2007), complementarity can be defined as a relation in which the increase in one factor  $x$  increases the return  $\pi$  of another factor  $y$ . The function can be expressed as  $\pi = f(x, y)$  such that  $\partial^2\pi/\partial y\partial x > 0$ . However, a relation of complementarity may in a second movement

be understood as an emergentist interdependence relation; a relation between parts that produces a totality, which is not only greater than the sum of the parts, but *novel*, meaning irreducible to the parts. This notion of complementarity thus links increasing returns to emergent macro-structures.

Inertia is at the core of explaining the reproduction of structures. In physics, inertia implies the amount of resistance of objects to a change in its state of motion. In economics "inertia" may be said to lie in the feasibility of changing a fact. The path dependent nature of structures, historical facts, explains in part why they tend to be reproduced. Once decisions have become facts, investments or in other ways materialized, it is often manifestly unprofitable, costly, inefficient or risky for agents to make changes. Uncertainty, is in itself a deep cause for inert or routinized behavior, closely linked to path dependence (see below). What is more, complementarities *between structures* add another dimension to the issue of reproduction. Traditions and routines (Braudel, 1958; see also Nelson and Winter, 1982), informal and formal rules (North, 1991) are themselves "structures" that not only solve the fundamental uncertainty inherent in economic exchange, but may reinforce other structures. To Althusser, the reproduction of the capitalist mode of production was governed by the superstructure, ideology, and the ideological apparatus. To Gramsci, the reproduction of the capitalist mode of production was aided by *hegemony*. Like the cross-linking of polymer chains in vulcanization processes create more durable materials, mutually reinforcing structures may work as strong factors behind the reproduction of an overall structure.

What then drives agents to transform structures? In a very generic sense, conflict appears to be the common denominator to those accounts that describe endogenous driving forces to (structural) transformation. In Dahmén's framework this emerges as "transformation pressure" or imbalances. Several students of technology have also pointed to that problems and imbalances may be systemic in character: lack of complementarities and technological imbalances spur and motivate "gap filling" innovations (Rosenberg, 1969; Hughes, 1983). Nathan Rosenberg (1969) noted that "The history of technology is replete with examples of the beneficent effects of this sort of imbalance as an inducement for further innovation" (Rosenberg, 1969, p. 10). A very similar view has been offered by Thomas Hughes' (1983; 1987) analysis of 'sociotechnical systems' that evolve through the emergence of 'salients' and 'reverse salients'. Reverse salients are backwards, underperforming components of the sociotechnical system, that hamper the development of the sociotechnical system as a whole. Such mechanisms are also easily found in other frameworks that center on explaining changes in various kinds of structure. In Kuhn's *The Structure of Scientific Revolutions*, the dominating mode of change in paradigms lies in a conflict between scientific expectations and results, which is resolved by way of exploration: "Discovery commences with the awareness of anomaly, i.e. with the recognition that nature has somehow violated the paradigm-induced expectations that govern normal science. It then continues with a more or less extended exploration of the area of anomaly. And it closes only when the paradigm theory has been adjusted so that the anomalous has become the expected" (Kuhn, 2012 [1962], p. 52–53). Similarly, in the view of Cyert and March (1963), problems, such as unsatisfactory technological or economic performance or intra-firm conflicts between antagonistic groups, would stimulate search for better products and processes. These and similar reasonings have been applied to social conflicts such as strikes, frequently linked to crises, wage reductions and discontent



**Table 1** Summary of structural phases and endogenous mechanisms

<i>Structural phase</i>	<i>Endogenous mechanisms</i>
Emergence (M2a)	Complementarity, increasing returns
Reproduction (M2b)	Inertia, sunk costs, traditions, routines, increasing returns, complementarity
Transformation (M2c)	Conflict, imbalances, incompleteness, absence

spurred by problems in the work environment, unemployment, or welfare cuts (see theories of relative deprivation, e.g. Davies, 1962).

Conflict, the absence of complementarity, imbalances, imperfections, or ontological absence form then a real basis of a dialectic that drives endogenous structural change. While creative responses to such imbalances or absences could well be teleological (in the sense intentional) from the point of view of agents, it must be considered teleonomic from the point of view of the whole, since there is no umpire or planner that organizes the evolutionary process of discovery.

If such contradictions occur at the structural level, the structure may be said to have entered into diminishing returns. Such endogenously generated decline of structures are present in both Marxian and Schumpeterian thinking. The Marxian analysis of the capitalist mode of production sought out internal contradictions. With respect to the tendency of the rate of profit to fall, Marx argued that "Capitalist production constantly strives to overcome these immanent barriers, but it overcomes them only by means that set up the barriers afresh and on a more powerful scale" and hence "The true barrier to capitalist production is capital itself" (Marx, 1991 [1894], p. 358). To Marx the contradiction both motivated technological change (which, being labor-biased however would accentuate the contradictions) and the eventual demise of capitalism. In Schumpeterian models of industry life cycles, diminishing returns arise from standardization of products, intensified competition and the exploitation and exhaustion of technological opportunities (see e.g. Gort and Klepper, 1982). Schumpeterian theories of technological change, and some Marxist theories of capitalism (e.g. Mandel, 1975) are in general open towards the possibility that structural decline may be suspended, but the underlying factors are exogenous or "semi-autonomous".

### 3.3 Endogenous structural change and emergence of macro-structure - a mathematical illustration

I will conclude this discussion by illustrating an alternate way of thinking structure and endogenous structural change. The mechanisms underlying structural change, found in Dahmén's framework and in the previous review, are summarized in Table 1. The Table indicates at once three modes of the analysis of endogenous structural change.

Most of these mechanisms and the notions of structure and structural change can be illustrated in a basic game-like framework. with agents  $a \in (1, 2, \dots, N)$ , a set of alternatives  $A$  and choices  $k \in (1, 2, \dots, K)$ ,  $k \in A$ . Define the number of agents choosing alternative  $k$  as  $N_k$  (where  $\sum_k N_k = N$ ) and a payoff function  $\pi_k$  at time  $t$ . Agents are for simplicity assumed to follow satisficing behavioral rules, i.e. agents evaluate payoffs for a current choice  $k$  and

$$\begin{cases} \text{choose } k \text{ if } \pi_k \geq L \\ \text{move to } j \in A \text{ with probability } P_{kj} \text{ if } \pi_k < L \end{cases} \quad (1)$$

This equation specifies the conditions of stability and change of choices, and by extension the conditions of reproduction and transformation of structures. In this framework the behavior of the system is determined by two facets: 1) the pay-off function, which determines what choices are profitable given the set of other choices, and 2) the transition probabilities between choices, i.e. the possibility that certain alternatives are unknown and/or improbable to reach from certain sets of choices. Clearly, the transition probabilities open up the possibility of path dependence (Arthur et al, 1987). Moreover, the notion that some alternatives are unknown and must be discovered is the basis of a evolutionary process in which novelty may result from the exploration of the space of choices. At this juncture, I will however restrict the discussion only to the specification of the pay-off function.

Payoffs are a function of the number of agents  $N_k$  choosing option  $k$ . In a simultaneous interdependent system the payoffs are modelled as linear functions of  $N_k$  according to

$$\begin{pmatrix} \pi_1 \\ \pi_2 \\ \vdots \\ \pi_K \end{pmatrix} = \begin{pmatrix} \beta_{11} & \beta_{12} & \dots & \beta_{1K} \\ \beta_{21} & \beta_{22} & \dots & \beta_{2K} \\ \vdots & \vdots & \ddots & \vdots \\ \beta_{K1} & \beta_{K2} & \dots & \beta_{KK} \end{pmatrix} \times \begin{pmatrix} N_1 \\ N_2 \\ \vdots \\ N_K \end{pmatrix} \quad (2)$$

where  $\beta_{kj} \in \mathbb{R}$  and for  $k = j$ ,  $\beta_{kj} \leq 0$ . The later assumption is due to that agents making the same choices compete for payoffs.

By contrast in a historically evolving system, payoffs evolve depending on the choices of agents. In order to introduce such an impact consider as an example a system in which the evolving payoff function of choosing an option  $k$  is

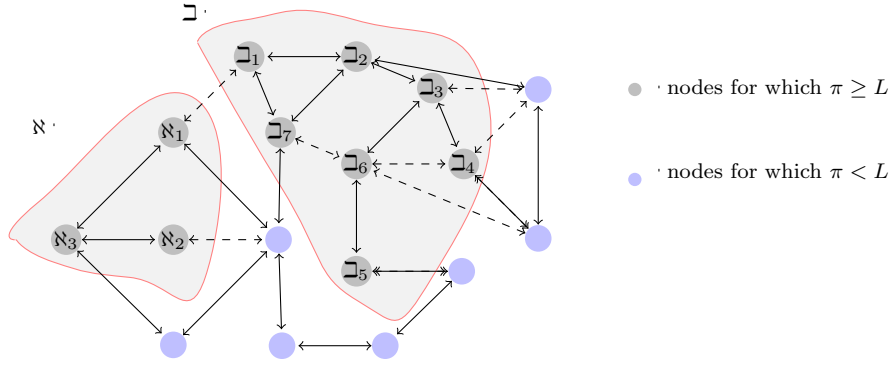
$$\pi_{kt} = \mathbf{B} \times \frac{\sum_{t=0}^t \alpha^t N_{kt}}{\sum_{t=0}^t \alpha^t N_t} \quad (3)$$

and where  $\mathbf{B}$  is again a  $K \times K$  matrix of coefficients  $\beta_{kj}$  and  $0 < \alpha < 1$  is a parameter stating the dependence of past choices. It is possible to rewrite the system to

$$\pi_{kt} = \mathbf{B} \times \left( \frac{\alpha N_{kt}}{N} + \frac{\sum_0^{t-1} (\alpha^{t+1} N_{kt})}{N} \right) \quad (4)$$

Thus payoffs are a weighted sum of the share of agents having chosen at some point in time the option  $k$ . Thus payoffs are dependent on both current and previous choices. Unlike the simultaneous model, the path of choices previously made determines which choices are "profitable" (or not) at time  $t$ . Or, if you will, the "causal efficacy" of structure is observed in the influence of historical choices on

**Fig. 1** Illustration of two structures ( $\aleph$  and  $\beth$ ) in a graph  $\Gamma$  with edges  $E$  as pairs of vertices  $(m, n) \in E$  such that  $\frac{\partial \pi_{m \in A}}{\partial N_{n \in A}} > 0$  or  $\frac{\partial \pi_{n \in A}}{\partial N_{m \in A}} > 0$ .



Note: Edges and dashed edges denote positive and negative values respectively.

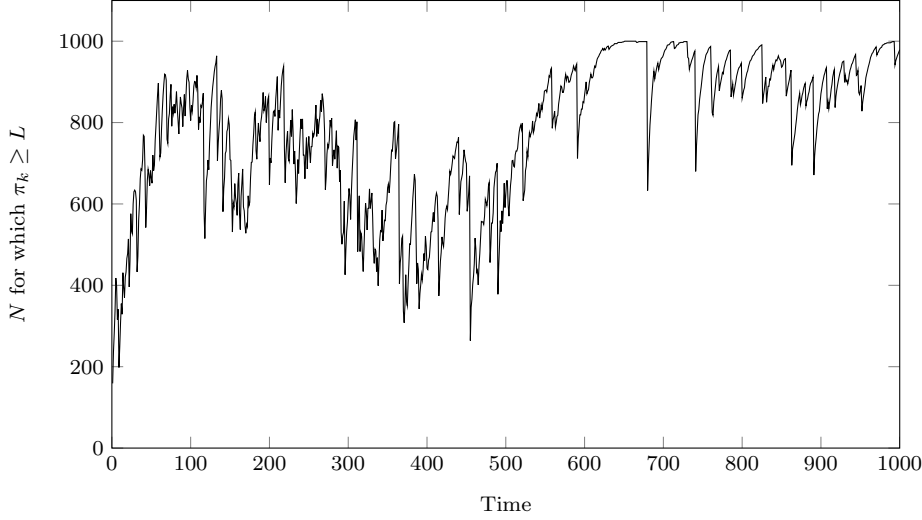
the current set of profitable choices. Thus, the historicity of the system provides "support" or "obstacles" for certain choices.

Thus our system consists of a behavioral rule for the reproduction or change of current choices (eq. 1) and a function (eq. 2 and eq. 4) in which choices (current or previous) determine the payoffs. Using this particular framework I advance that a **structure** can be defined *in general* as a subset of choices  $S \subset A$ , for which two criteria hold. First, all the parts of the structure are *connected* in terms of positive interrelations. In our case, we may discern such sets in the graph of  $\frac{\partial \pi_{\mu \in S}}{\partial N_{\nu \in S}}$  (i.e.  $\beta_{\mu\nu}$  in eq. 2 and  $\frac{\alpha}{N} \beta_{\mu\nu}$  in eq. 4). By connectedness it is here implied that in a network of positive relations, regardless of direction, any vertex  $\mu \in S$  can be reached from any other vertex  $\nu \in S$ . Formally, define the edges  $E$  of a graph as pairs of vertices  $(m, n) \in E$  such that  $\frac{\partial \pi_{m \in A}}{\partial N_{n \in A}} > 0$  or  $\frac{\partial \pi_{n \in A}}{\partial N_{m \in A}} > 0$ . A structure is then connected if for any two vertices  $\mu$  and  $\nu$  in  $S$ , there is a path from  $\mu$  to  $\nu$ . Second, the choices within the structure are profitable:

$$\forall \mu \in S, \pi_{\mu \in S} \geq L \quad (5)$$

Observe that this definition allows *both positive and negative* interrelations between parts of the structure, and hence potential instability. A structure is thus a (potentially) stable set of choices, ranging from equilibrium positions to temporarily stable sets of choices that are slowly counteracted by negative interrelations. In general, equilibrium positions are positions  $N_{\mu}^*$  such that  $\forall \mu \in S, \pi_{\mu} \geq L$  and  $\forall \mu \in S, \Delta \pi_{\mu} \geq 0$ . Conversely, undermined positions of stability are positions such that  $\forall \mu \in S, \pi_{\mu} \geq L$  and  $\forall \mu \in S, \Delta \pi_{\mu} < 0$ .

Figure 1 illustrates the proposed notion of structure in an undirected graph with adjacency matrix  $\frac{\partial \pi_{\mu \in S}}{\partial N_{\nu \in S}}$ , assumed symmetric for simplicity. The example shows two sets of vertices  $\aleph$  and  $\beth$  for which the nodes involved pay-offs above aspiration levels ( $\pi \geq L$ ) are connected in terms of positive inter-relations (edges).  $\aleph$  has only positive interactions. Consequently, structural breaks can only occur in terms of relations to the vertices outside of  $\aleph$ . By contrast, the structure could possibly be undermined by the negative relations within  $\beth$ .

**Fig. 2** Simulation with endogenous structural instability and episodes of crisis.

Y axis shows the number of agents for which payoffs are larger 0. The number of agents  $N = 1000$

It is clear that in eq. 4 the matrix of parameters  $\mathbf{B}$  determines the prevalence of stable and unstable structures, together with the history of the system. Now, it is possible to understand the system in terms of the found underlying assumptions about the interrelations between agents in terms of complementarities or increasing returns and conflict or imbalances, summarized in Table 2. Three types of relations between choices are possible to discern in considering the elements of the Jacobian of the payoff function  $\nabla_{kj} = \frac{\partial \pi_k}{\partial N_j}$ , which in the first simultaneous systems is equal to  $\mathbf{B}$  and equal to  $\frac{\alpha}{N} \mathbf{B}$  in the evolving system. Complementarities between two choices exist if for two choices  $k$  and  $j$ ,  $\frac{\partial \pi_k}{\partial N_j} > 0$  and  $\frac{\partial \pi_j}{\partial N_k} > 0$ . A rivalrous relation between two choices  $k$  and  $j$  exist if  $\frac{\partial \pi_k}{\partial N_j} < 0$  and  $\frac{\partial \pi_j}{\partial N_k} < 0$ . For the cases when  $k = j$ , these relations are equivalent to increasing and decreasing returns respectively. Finally, "exploitative relations" are enabled if for two choices  $k$  and  $j$ ,  $\frac{\partial \pi_k}{\partial N_j} > 0$  and  $\frac{\partial \pi_j}{\partial N_k} < 0$ .

Thus complementarities, exploitative and rivalrous relations can be defined respectively as relations that mutually enhance payoffs, benefits one at the expense of the other and mutually decrease payoffs. Clearly, complementary choices enable structure, as defined in eq. 5, to emerge, while rivalrous relations undermine structures. Exploitative relations may reproduce or undermine a structure, depending on the state of the system.

A core point here is that in the simultaneous system (eq. 2), such relations exist simultaneously but will not interfere with the structure once it is attained, since by definition payoffs only change when choices change:  $\Delta \pi_k = \mathbf{B} \times \Delta N_k$ . By contrast, in the historically evolving system (eq. 4) the level of payoffs may be sufficient for agents to continue to reproduce the system, while payoffs decrease as a consequence of historical choices. Macro-structure may thus emerge, but it may be inherently stable or unstable, depending on the state of the system. Figure 2

shows a simulation of the system described by eq. 4, in which the system tends towards the emergence of macro-structure but due to a prevalence of negative relations is intermittently undermined by rivalrous and/or exploitative relations leading to structural crises and restructuring towards choices with payoffs  $\pi \geq L$ .

#### 4 The four modes of causal-structural analysis. Summary

Recent attempts to understand structural change as endogenous to economic mechanisms challenge the traditional division of labor between economics and economic history. This challenge calls for approaches to integrate economics and economic history, i.e. causal and structural analysis. This paper has aimed to expound how the notion of endogenous structural change is thought and can be thought in terms of underlying mechanisms in order to aid empirical analysis of evolving structures. By surveying a broad literature, I believe to have arrived at some suggestions of how causal analysis and structural analysis can be integrated and how structural change can be understood and studied empirically in terms of a set of basic mechanisms.

On the conceptual level, this paper has shown that the ostensible paradox in thinking endogenous structural change stems from notions which are inherently ahistorical (Bhaskar, 1998 [1979]). When history is introduced, in our particular model when payoffs evolve as a result of choices, endogenous stability as well as endogenously generated crises and instability is possible. Positive and negative relations among micro-agents underpin three facets of structural change: emergence, reproduction and transformation. These relations, specified by Dahmén and in contributions in evolutionary economics, economics of complexity and Marxian theories, among others, substantiate notions of endogenous structural change, and point to areas of possible empirical observation of economic structures and structural change.

The issue facing empirical research is how to analyse and register mechanisms underlying the emergence, reproduction and eventual decline of structures. This paper has found four modes of structural analysis which can be connected with causal analysis of economic phenomena. The causal-structural analysis is then a description of not only stable causal mechanisms, but also a description of the interrelations between a potentially evolving causal mechanism and structure. The first mode (*M1*) is to determine the structural boundaries, i.e. the observation of structural stability. In Åkerman's research, periods of structural stability could be studied by using structural indicators. In Swedish economic historical research, structural analysis along the lines of Åkerman has first and foremost been carried out by way of analysis of the temporal boundaries of structures through the use of macro-oriented "structural indicators", such as the investment ratio, the wage share or the Gerschenkron index.

In a second mode of analysis (*M2*), structural change is understood through causal analysis of the driving forces of structural change, incorporating them into the framework. This mode has three analytical facets that link causal mechanisms to structural change: how new structures emerge as a result of economic behavior (*M2a*) and how agency reproduces (*M2b*) or transcends existing structures (*M2c*). These modes of analysis stresses the study of the relationship between micro and macro. Dahmén's notion of development blocks extended Åkerman's structural

analysis by providing several key mechanisms underlying industrial transformation and structural change, making possible a conception of structural change not merely being exogenously imposed but also being the endogenous result of micro-behavior: "The microanalysis must thus aim for a macro-picture, i.e. it must comprise the influence of the microunits on their environment" (Dahmen, 1980, p. 38, translation by the author). Similarly, one may add, an integration of causal and structural analysis requires econometric or qualitative analysis of economic mechanisms to explicitly comprise their influence on their (structural) environment. Dahmén's theory of industrial transformation and his concept of development blocks thus suggest that macro-studies of structural change can be complemented by a more micro-oriented approach.<sup>10</sup>

It is here thus suggested that structural analysis, in general, may be carried out by observing structural stability and change establishing structural boundaries through the analysis of structural indicators (*M1*) and through the empirical analysis of underlying micro-mechanisms (*M2a*, *2b* and *2c*). The reviewed mechanisms previously summarized in Table 1 summarize the positive factors that underlie the emergence of structure, the inert factors that underlie the reproduction of structures, and the negative factors that underlie the transformation, or continued evolution of macro-structure.

It seems first of all to be through the study of complementarities and increasing returns that we may study the emergence and reproduction of economic, technological or other structures. Empirical studies of relations of complementarity are however difficult to conduct due to the evasive nature of complementary relations in complex systems. Clearly, such studies not only require an adequate grasp of the interdependence between choices of micro-agents but also the character of such interdependencies. As regards innovation studies, it seems that up until now the most viable path for empirical research consists in qualitative case studies. However, provided that positive interdependencies can be properly assessed, network analysis of interdependencies between e.g. industries, technologies, patents or innovations is a viable alternative to assess systematic interdependencies.

A principal factor underlying the reproduction of structure is also the *inertia*, by which in economic contexts is often understood quasi-irreversible investment, locally increasing returns, or sunk investment, a historically given fact, which by itself makes changes to the current state of affairs implausible, unprofitable or perhaps manifestly absurd. These are historical mechanisms that underlie the reproduction of structure, and, potentially create obstacles or disincentives to the transition from one societal, economic or institutional arrangement to another. With their source in fundamental uncertainty, routine, traditions and other types of informal institutions have in the history of mankind played a manifest role in e.g. creating stable forms of economic exchange, but are also a sources of inertia and resistance to change (Braudel, 1958; North, 1991). These mechanisms are also probably best studied in terms of micro-oriented analysis, be it qualitative or quantitative, asking the question: under what circumstances do agents reproduce the states of affairs? This is at once, possibly, a question of studying the "causal efficacy" of structures through the mechanisms by which structure tends

<sup>10</sup> In this tradition of thought, Schön (1994, 1998, 2010) integrated the analysis of structural indicators with a historical analysis of the driving forces of transformation and the implications of economic crises, thereby establishing structural boundaries and a historical generalization of the rhythm of technological change and industrial transformation in development blocks.

to reproduced. In the mathematical illustration given previously, such inertia was introduced through an impact of historical choices on payoffs, either in terms of increasing returns or complementarities between choices, thus increasing the "profitability" of certain choices, or in terms of making other choices "unprofitable".

Lastly, it seems to be by the study of imbalances and conflicts that we may find endogenous driving forces of structural change: in innovation systems, labor market relations, institutions, scientific paradigms and so forth. Again, micro-oriented studies of response to imbalances, conflicts and problems are likely to be rewarded with improved understanding of the mechanisms behind structural breaks, crisis and how alternatives to present orders of things emerge.

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