# Causality and Endogenous Structural Change in Economics and History

**Josef Taalbi**

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**Abstract** Causal inference in historical, complex systems is one of the core methodological issues of the social sciences. The problem is well-known: what are we to make of causal inference when the study object does not allow us to isolate causes and effects in well-controlled and repeatable experiments? These issues point towards notions of structural stability as prerequisites of economic analysis. Traditionally this has engendered a division of labor between economics and economic history, the task of economic history being that of studying the evolving constraints of economic analysis. Recent theorizing on endogenous structural change however challenges this view: 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. Rather such views appear to call for integration of causal and structural analysis.

This 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 search for mechanisms by which structural stability and change can be studied, the paper reviews debates on structure and agency in sociology and notions of emergence, conflict and inertia in various strands of economic theory, among which Hayekian, Marxian, institutional economics and recent advances in Schumpeterian and evolutionary economics have been especially noticeable. The paper especially notes and makes use of the critical and constructive contributions to made by two Swedish economists, Johan Åkerman (1896-1982) and Erik Dahmén (1916-2005), notable for developing theoretical and empirical frameworks that integrate economic historical and economic analysis. The findings of basic mechanisms underlying the emergence, reproduction and transformation of structures are crystallized into a simple mathematical model of endogenous structural change that stressed the historicity of the notion of structure as opposed to the caeteris paribus or equilibrium notions of structure in economics. The essay concludes by reflecting on possible ways of empirically studying the evolution of economic and social structures.

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

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J. Taalbi
Department of Economic History, Lund University. P.O. BOX 7083, Lund 22007 Sweden
Tel.: +46-46-2224352
Fax: +123-45-678910
E-mail: josef.taalbi@ekh.lu.se

## 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 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) 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 aims to study the points of contact between economic and economic historical analysis through a study of notions of causality, structure and structural change present in economic and economic historical discourse. How could the analysis of causal mechanisms be integrated with a conjoint study of changes in underlying structures? 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.

The essay begins with a discussion of some of the major underlying philosophical theme in thinking causality in economics and economic historical analysis. The paper then turns towards notions of structure in economic theory, showing the notions of structure in economic theory imply that structural change is exogenous to the mechanism under study.

In section 3 the analysis is turned towards alternative views on causality and structure and 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).

In section 4, 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 reflecting on challenges to the empirical study of the evolution of economic and social structures.

## 2 Approaches to causality and structure in economics

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 onto-epistemologies about how we perceive inter-relations between phenomena. More importantly, these notions are interrelated. In this section, I will try to illustrate how ontological positions on causality in mainstream economic theory point towards 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 "exogenized", or it is explicitly incorporated as a facet of causal mechanisms, thus making the causal analysis inseparable from structural analysis.

### 2.1 Humean causality and its impact in economics and economic history

What then is causality? From a certain vantage point, it could perhaps seem a bit odd that we are still discussing in terms of cause and effect, given its poor reputation in science and philosophy. David Hume defined causality as the constant conjunction of a cause $A$ with the effect $B$, where the cause is antecedent to the effect. The meaning of this view is a strict empiricism, implying that causality "can never be discovered merely from the ideas of the objects", but has to be learnt about from experience (Hume, 2012 [1738], p. 47). 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.

The influence of Hume on modern views was transmitted by the Cambridge analytical school, based on a similar atomism. While Hume did not doubt the ontology of causation, philosophers as Russell and Wittgenstein arguably harbored a more radical disbelief in the status of causation. Russell has famously stated:

> "the reason why physics has ceased to look for causes is that, in fact, there are no such things. The law of causality, I believe, like much that

> passes muster among philosophers, is a relic of a bygone age, surviving, like the monarchy, only because it is erroneously supposed to do no harm" (Russell, 1912, p. 1).

Similarly, Wittgenstein stated: "There is no possible way of making an inference from the existence of one situation to the existence of another, entirely different situation" and "There is no causal nexus to justify such an inference" (Wittgenstein, 2001 [1922], 5.135 and 5.136). The Vienna circle, the positivist movement and other followers of the Humean and logical atomist views were thus bred with an agnosticism or disbelief towards causation.Yet, as a goal of scientific endeavors, the notion of causality has lingered on. This owes much to the influence of Karl Popper's critical rationalist approach. As for a principle of causality, "the assertion that any event whatsoever *can* be causally explained", Popper was agnostic, or leaving it aside for metaphysics (Popper, 2002 [1935], p. 39). However, according to Popper, despite his agnosticism, the best one can do is to formulate falsifiable causal explanations, consisting of universal statements and singular statements, or initial conditions.

Incorporating these aspects of Popper's scientific view, the positivist stance on causality has needless to say been enormously influential, not only in economics, but also in economic history. This is despite the notion, held among others by Popper, that "historical sciences" are to be distinguished from generalizing sciences.[1] In launching a positivist agenda for the discipline of economic history, Hempel's 1942 essay "The function of general laws in history" played a particularly important role. In this essay Hempel argued that also in historical sciences, explanation of phenomena must be made in terms of general laws. According to Hempel (1942, p. 35), while the "description of particular events of the past" was undeniable as a characterization of the research of some historians, it was "unacceptable", "as a statement of the theoretical function of general laws in scientific historical research". Hempel crucially argued that idiography or "pure description" was inseparable from "hypothetical generalization" and "theory-construction" (Hempel, 1942, p. 46). Rather, historical explanation consisted in "explanation sketches", i.e. descriptions that contain references to well-founded general laws. Inspired by the work of Hempel, Meyer and Conrad (1957) put forth a positivist approach for the historical sciences, aiming to attack the problems of "the concepts of historical causality and explanation in a stochastic universe and to suggest how the analytic tools of scientific inference can be applied in economic historiography" (Meyer and Conrad, 1957, p. 524). Facing complexity and historicity, Meyer and Conrad (1957) argued for a methodology, according to which economic historians could seek out variations in exogenous variables (causes) that affect endogenous variables, together with sets of random shocks, representing historical events. This general approach quickly became canonical in cliometrics. However, economic historians have been forced to stay acutely aware of the problems induced by complexity and historicity, among which are the potential instability of generic causal relations.

Following the imperative to search for general, repeatable, patterns of causation, there was a need for inventive approaches to conceive, model or empirically

[1] "From our point of view, there can be no historical laws. Generalization belongs simply to a different line of interest, sharply to distinguished from that interest in specific events and their causal explanation which is the business of history. Those who are interested in laws must turn to the generalizing sciences" (Popper, 2010 [1945], p. 292).

infer causal relations in complex systems. It is possible to argue that Humean notions of causality have typically induced empirical strategies that center on reproducing closed systems or observing constant conjunctions. As noted by Moneta (2005), the probabilistic approach to causality is a canonical econometric expression of the Humean view. Granger's (1969) hugely influential concept of causality was presented by that 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.[2] A 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).[3]

Other approaches have attempted to solve the problem of causality in historical systems by the logic of counterfactuals. The American philosopher David Lewis has, among many others, drawn attention to that Hume, in fact, defined causation twice over: on the one hand as a constant conjunction of sets of events and on the other hand a relation of necessity: "if the first object had not been, the second never had existed" (Hume, 2011 [1748], Section VII). Lewis regarded identification of constant conjunctions between events to be fraught with problems.[4] Hence, its prospects gloomy.[5] In its stead, Lewis argued for the logic of counterfactuals: if $c$ and $e$ are two actual events such that $e$ would not have occurred without $c$, then

[2] 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 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 conglomorate in the Ruhr area may well be).

[3] 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.

[4] *Reverse causality*, *epiphenomena*: the presence of common causal factors behind hypothesized cause and effect, and *preempted potential causes*, i.e. something that did not cause a certain effect, but would have in the absence of the actually caused.

[5] "It remains to be seen whether any regularity analysis can succeed in distinguishing genuine causes from effects, epiphenomena, and preempted potential causes - and whether it can succeed without falling victim to worse problems, without piling on the epicycles, and without departing from the fundamental idea that causation is instantiation of regularities" (Lewis, 1973, p. 557).

$c$ is a cause of $e$. In the emerging cliometric approach in economic history, counterfactual analysis was widespread, Fogel's counterfactual analysis of the impact of railroads on economic growth being the seminal contribution (Fogel, 1964).

However, counterfactual logic, as the observation of constant conjunctions, is also susceptible to the issues of complexity. Sources of criticism are for instance the problem of showing that there is no one other factor that may cause both the hypothetical *explanans* and *explanandum*, or the problem of formulating a model that could account for the number of other ways in which the effect could be actualized without the particular cause under consideration. The logic of counterfactuals, like the Humean constant conjunction, thus tacitly relies in practice on assuming the existence of a certain, stable, causal structure and the epistemological possibility of isolating causal mechanisms.

## 2.2 The dual notions of structure in economics.

Examining notions of structure in economics more closely we observe, like many have before, that there are two ways in which structure is introduced:

- as *caeteris paribus*. An exogenous state of affairs unaffected by the causal mechanisms under study, or
- 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.

Let us ponder upon the meaning and implications of these modes of thought. First of all, structure is in economics present in the *ceteris paribus* of mathematical models, those behavioral or arithmomorphic assumptions of other things being equal that in practice imply ignoring "the element of time".[6] Rather than being a special case however, the *ceteris paribus* is, in a trivial sense, ubiquitously present in mathematical modelling, through the implicit assumptions of invariance introduced in parameters, or particular behavioral assumptions employed to solve a system of equations. The behavioral assumptions introduced link agency to incentives and structural properties of the situation at hand, such as uncertainty, information and (market) power. These tacit assumptions thus imply stable institutional structures. Parametric assumptions, when introduced in economic models, likewise may imply stable (unchanged) production structures or the like. The parametric assumptions also applies to the econometric models that lay claims to test or model causation, whether in Simon's system of linear equations, the structural VAR-approach or tests for Granger causality. They all obviously presuppose stable

[6] As was expressed by 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).

structural coefficients (parameters), and can so only be valid in certain spatio-temporal domains. Cliometricians are reminded daily of this, or, as acknowledged by some of the architects of cliometrics: "the greater the number of years covered by the empirical study, the fewer institutional or structural conditions that can be considered fixed, and consequently the greater the need for expanding the number of specific explanatory variables included in the model. This is essentially the difficult problem of "structural change" that makes the economic theorist's box of *ceteris paribus* conditions something else than fixed" (Meyer and Conrad, 1957, p. 542). Some modern econometric views imply similar implicit notions of structure as ceteris paribus conditions as they are centered on abstracting from, rather than including, structural conditions in the search for stable economic mechanisms.

Second, structure is also be present as a *resulting* property of the system studied, typically as an *equilibrium* that is realized in the absence of external disturbances. Some of the more familiar criticisms towards the methodological corollaries of the equilibrium concept were 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 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.

One may accurately object to this critique of the equilibrium concept on the basis of the fact that major leaps in macro-dynamics have been taken towards the study of structural change through the emergence of non-linear dynamics. A good example is Richard M Goodwin, whose principal scientific endeavors were to explain cycles and try to account for *endogenous* structural change, why he came to devote his scientific career to non-linear dynamics. Macro-dynamics, builds on the dual presence of "structure" in the stable parameters fed into the model and in the equilibrium outcome. The traditional macro-models of Frisch (1933), Kalecki (1939), Harrod (1939), and the later contributions of Goodwin (1951, 1967) or similar models were aimed at deriving business cycle phenomena from assumptions, in which the ceteris paribus is embodied sets of structural coefficients, or behavioral assumptions that rely on fixed or stable institutional preconditions. [7] As van der Pol had shown in the 1920s, non-linear equations could generate limit

[7] The Kaleckian models for instance derive the profit equation from the aggregate identities of income and expenditures. However, endogenizing investment behavior to produce a model

cycles, i.e. cyclical equilibrium solutions.[8] Goodwin later took this work further. With the discovery of chaotic dynamics it was shown that the solutions to non-linear systems can undergo *bifurcations*, a change in the qualitative character of equilibrium solutions, or, put in a more involved way, a change in the topological structure of a phase portrait, as a parameter is varied.

However, what Goodwin could never escape is that the change in the qualitative character of solutions is nevertheless caused by an *imposed* shift in the parameters (the structural coefficients). In this way, the effects of changes in the structural coefficients can be registered and analyzed, while at the same time the "driving forces" of such structural changes are never purely endogenous. While non-linear dynamics is thus capable of registering a correspondence between the structural coefficients (input) and the topological structure (output), it cannot move past an imposed, and therefore strictly speaking exogenous, change in the parameters.[9]

### 2.3 A division of labor between causal and structural analysis

It is clear from the previous review that a division of labor between causal analysis and structural analysis, i.e. the analysis of structural stability and change, in part follows from the Humean notion of causality. The dominant approaches to causality in econometrics and economic history center on finding stable, generic mechanisms, where permissible, avoiding or abstracting from structural change. This methodology fits well with the ubiquitous notions of caeteris paribus and equilibrium, which posit only stability, but cannot incorporate structural change as a facet internal to the analysis. While well-supported and careful Granger analysis, instrumental variable analysis and natural experiments can provide important evidence of causal patterns in beneficial circumstances, these approaches do not seem rid us of the haunting notion that, in complex systems, scientific explanation requires due care taken to multiple patterns of causation and the historicity, and potentially strict temporal boundaries set by the evolution of economic relations.

## 3 Towards an integration of causal and structural analysis

The separation of causal analysis and the analysis of structural change is at odds with the notion that institutions, technological systems, production and market structures may at once support or alter causal mechanisms while themselves resulting from economic behavior. Clearly, if changes in production, technologies and institutions are endogenous to economic mechanisms, we must look for ways of transcending the division of labor between causal and structural analysis.

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of economic cycles, Kalecki (1939), was obliged to assume a monotonous linear dependence of investment on savings, profit growth, and the rate of change in the stock of capital.

[8] Frisch, Kalecki and Harrod all modelled cycles using linear equations, which however could not give rise to perpetuated economic cycles. According to Goodwin, "Frisch misled a generation of investigators by resolving the problem with exogenous shocks, whereas already in the 1920s van der Pol had shown (as Frisch should have known) that a particular form of non-linear theory was the appropriate solution. His solution leads to a limit cycle" (Goodwin, 1990, p. 10).

[9] Specifically, if dynamic equilibrium is taken to involve a set of variables, those variables can never be the causes of a structural change.

### 3.1 Causal ontologies in the face of complexity

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, 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.

An example of thinking 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 macroeconometric 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[10], 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.

### 3.2 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:

- 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 3.3 and 3.4, by reviewing Johan Åkerman's "causal analytical" notion of structure and Erik Dahmén's notion of "development blocks" as examples of approaches that integrate causal and structural analysis, pointing towards the study of structural change as endogenous to economic mechanisms. Åkerman and Dahmén developed methodological frameworks that explicitly aimed to connect causal analysis with the empirical study of structural change. Like many others 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. In reviewing these frameworks, I hope to indicate what is unique and generalizable beyond economics in their methodologies, though the practical subject matters of their scientific projects have been limited to economic development and industrial transformation.

### 3.3 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

[10] "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).

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).[11]

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 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).

[11] 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).

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.

Åkerman (1944, pp. 27-28) clarified that such search for driving forces is a process, one is temped 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.[12] 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). *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 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.

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

[12] "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 an other ostensibly closed system and from there to another ostensibly closed proces, etc." (Åkerman, 1944, pp. 27-28, translation by JT).

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 steps:

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

### 3.4 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. While not widely familiar, 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" (Dahmen, 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.[13] 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 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.

[13] 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).

### 3.5 General lessons

The present review has uncovered the substantial ground in Åkerman's and Dahmén's framework to analyse endogenous structural change. 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.

## 4 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 pick up the thread of what is precisely meant with endogenous structural change. Phrased otherwise: how can one think structural change as arising within the frames of structure without being trapped in circular reasoning or tautology?

### 4.1 Structure in history and the social sciences

The main discussion has concerned the relation between agency and structure, and it is in the attempts to solve this issue that 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.[14] 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 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

[14] "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).

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)[15], 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).

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.

### 4.2 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

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

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 levels at which structural change must be explained: the emergence of structure, its reproduction, and transformation. Some such mechanisms 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 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

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

| *Structural phase* | *Endogenous mechanisms* |
|---|---|
| Emergence | Complementarity, increasing returns |
| Reproduction | Inertia, sunk costs, traditions, routines, increasing returns, complementarity |
| Transformation | Conflict, imbalances, incompleteness, absence |

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".

### 4.3 Endogenous structural change and emergence of macro-structure - a mathematical illlustration

The mechanisms underlying structural change, found in Dahmén's framework and in the previous review, are summarized in Table 1. Most of these mechanisms and the various notions of structure and structural change can be illustrated in a basic game-like framework. with agents $a \in (1, 2, ..., N)$, a set of alternatives $A$ and choices $k \in (1, 2, .., K)$, $k \in A$. 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

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

This equation specifies the conditions of stability and change of choices, and by extention the conditions of reproduction and transformation of structures. In this framework the behavior of the system is determined by two facets: 1) the payoff 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

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

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

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

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

$$\pi_{kt} = \mathbf{B} \times \left( \frac{\alpha N_{kt}}{N} + \frac{\sum_{0}^{t-1} \left( \alpha^{t+1} N_{kt} \right)}{N} \right) \tag{4}$$

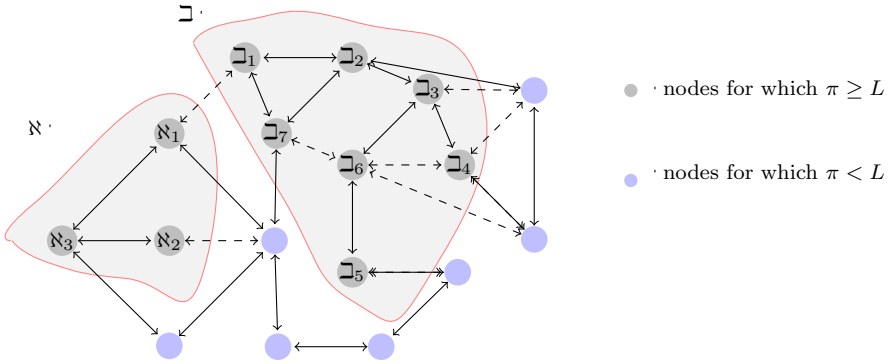
Thus payoffs are a weighted sum of the share of agents having chosen at some point in time the option $k$. Thus payoffs are dependent on both current and previous choices. Unlike the simultaneous model, the path of choices previously made determines which choices are "profitable" (or not) at time $t$.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

$$\forall_{\mu \in S}, \pi_{\mu \in S} \geq L \tag{5}$$

Observe that this definition allows *both positive and negative* interrelations between parts of the structure, and hence potential instability. A structure is thus a

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




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

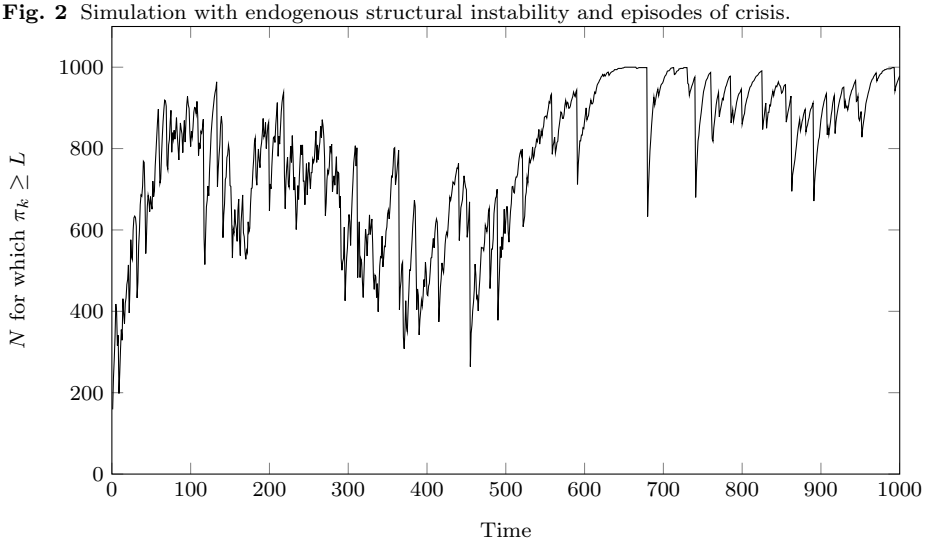
(potentially) stable set of choices, ranging from equilibrium positions to temporarily stable sets of choices that are slowly counteracted by negative interrelations. In general, equilibrium positions are positions $N^*_\mu$ such that $\forall_{\mu \in S}, \pi_\mu \geq L$ and $\forall_{\mu \in S}$, $\Delta \pi_\mu \geq 0$. 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 א and ב for which the nodes involved pay-offs above aspiration levels ($\pi \geq L$) are connected in terms of positive inter-relations (edges). א has only positive interactions. Consequently, structural breaks can only occur in terms of relations to the vertices outside of א. By contrast, the structure could possibly be undermined by the negative relations within ב.

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 struc-

**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 $N = 1000$

tures. 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 $\pi \geq L$.

## 5 Joining causal and structural analysis. Conclusions and 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.

In this paper I have, along the lines of Bhaskar's understanding of structure, and by using a mathematical illustration, shown that the ostensible paradox in thinking endogenous structural change stems from notions which are inherently ahistorical. 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, making 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. Using Åkerman and Dahmén as examples, we have found two suggestions on how structures can be studied in terms of macro- and micro-analysis. First, 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. Second, structural change is understood through causal analysis of the exogenous driving forces, incorporating them into the framework. 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.[16]

It is here thus suggested that structural analysis, in general, may be carried out by observing structural stability and change through the analysis of structural indicators and through the empirical analysis of underlying micro-mechanisms. The reviewed factors, previously summarized in Table 1, underlying the emergence, reproduction and transformation and structures in the broader literature provides suggestions of how empirical research can approach the observation of structure and structural change. These factors 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.

[16] 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.

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 (as regards economic flows and innovation systems, see McNerney et al, 2013; Garbellini and Wirkierman, 2014; Taalbi, 2014).

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. 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 "improfitable".

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.

## References

Agassi J (1975) Institutional individualism. British Journal of Sociology pp 144–155

Åkerman J (1939) Ekonomisk teori. 1, De ekonomiska kalkylerna. Gleerup, Lund

Åkerman J (1944) Ekonomisk teori. 2, Kausalanalys av det ekonomiska skeendet. Gleerup, Lund

Åkerman J (1949) Strukturgränser i svensk industrialism. Ekonomisk tidskrift 51(1):1–18

Åkerman J (1960) Theory of industrialism: causal analysis and economic plans. 19, CWK Gleerup

Althusser L, Balibar E (1970) Reading Capital. NLB, London

Angrist JD, Krueger AB (2001) Instrumental variables and the search for identification: From supply and demand to natural experiments. The Journal of Economic Perspectives 15(4):69–85

Antonelli C, et al (2008) Localised technological change: towards the economics of complexity. Routledge

Aristotle (2009) Metaphysics (translated by W.D. Ross). NuVision, LaVergne, TN.

Arrow K (1994) Methodological Individualism and Social Knowledge. The American Economic Review 84(2):pp. 1 – 9

Arthur BW, Ermoliev YM, Kaniovski YM (1987) Path-dependent processes and the emergence of macro-structure. European journal of operational research 30(3):294–303

Arthur WB (1989) Competing technologies, increasing returns, and lock-in by historical events. The Economic Journal 99(394):116–131

Arthur WB (1990) Positive feedbacks in the economy. Scientific American 262(2):92–99

Arthur WB (1994) Increasing Returns and Path Dependence in the Economy. Ann Arbor: University of Michigan Press

Arthur WB, Durlauf SN, Lane DA (1997) The economy as an evolving complex system II, vol 28. Addison-Wesley Reading, MA

Bhaskar R (1998 [1979]) The Possibility of Naturalism : a philosophical critique of the contemporary human sciences, 3rd edn. Routledge, London

Bhaskar R (2008) Dialectic: The pulse of freedom. Taylor & Francis US

Bhaskar R (2008 [1975]) A Realist Theory of Science, [new ed.] edn. Verso, London

Braudel F (1958) Histoire et sciences sociales: la longue durée. Annales Histoire, Sciences Sociales 13(4):725–753

Bresnahan TF, Trajtenberg M (1995) General purpose technologies 'Engines of growth'? Journal of econometrics 65(1):83–108

Carlson B (1999) The institutional ideas virus: the case of Johan Åkerman. Journal of the History of Economic Thought 6(1):71–86

Cyert RM, March JG (1963) A behavioral theory of the firm. Englewood Cliffs, NJ: Prentice-Hall

Dahmén E (1950) Svensk Industriell Företagarverksamhet: kausalanalys av den industriella utvecklingen 1919-1939., vol 1. Industriens Utredningsinstitut

Dahmen E (1980) Hur studera industriell utveckling? In: Eliasson G, Dahmen E (eds) Industriell Utveckling i Sverige: teori och verklighet under ett sekel, Industriens UtredningsInstitut, Stockholm, pp 25–62

Dahmén E (1991a) Development blocks in industrial economics. In: Carlsson B, Henriksson RGH, Dahmén E (eds) Development Blocks and Industrial Transformation : the Dahménian Approach to Economic Development, Industrial Institute for Economic and Social Research (IUI), Stockholm, pp 136–148

Dahmén E (1991b) Schumpeterian dynamics: Some methodological notes. In: Carlsson B, Henriksson RGH, Dahmén E (eds) Development blocks and industrial transformation : the Dahménian approach to economic development, Industrial Institute for Economic and Social Research (IUI), Stockholm, pp 125–135

Dahmén E (1991 [1942]) Economic-structural analysis. reflections on the problem of economic development and business cycle fluctuation. In: Carlsson B, Henriksson RGH, Dahmén E (eds) Development Blocks and Industrial Transformation : the Dahménian Approach to Economic Development, Industrial Institute for

Economic and Social Research (IUI), Stockholm, pp 25–41
Dahmén E (1993) Research on Railways in a Historical Perspective. In: Dahmén E, Whitelegg J, Hultén S, Flink T (eds) High speed trains: Fast tracks to the future, Leading Edge in association with Stockholm School of Economics, Hawes, pp 18–25
David PA (1985) Clio and the Economics of QWERTY. The American Economic Review 75(2):pp. 332–337
Davies JC (1962) Toward a theory of revolution. American sociological review pp 5–19
De Haan J (2006) How emergence arises. Ecological Complexity 3(4):293–301
Erixon L (2011) Development blocks, malinvestment and structural tensions–the Åkerman–Dahmén theory of the business cycle. Journal of Institutional Economics 7(01):105–129
Fogel RW (1964) Railroads and american economic growth: essays in econometric history
Freeman C, Louça F (2001) As time goes by: the information revolution and the industrial revolutions in historical perspective. Oxford University Press, New York
Frisch R (1933) Propagation Problems and Impulse Problems in Dynamic Economics. G. Allen & Unwin
Garbellini N, Wirkierman AL (2014) Blocks and circularity in labour requirements: An interplay between Clusters and Subsystems in the EU. Structural Change and Economic Dynamics 28:60–74
Gille B (1978) Histoire des techniques : technique et civilisations, technique et sciences. Gallimard, Paris
Goodwin RM (1951) The nonlinear accelerator and the persistence of business cycles. Econometrica: Journal of the Econometric Society 19(1):1–17
Goodwin RM (1967) A growth cycle. Socialism, capitalism and economic growth pp 54–58
Goodwin RM (1990) Chaotic Economic Dynamics. Clarendon Press Oxford
Gort M, Klepper S (1982) Time paths in the diffusion of product innovations. Economic journal 92(367):630–653
Granger CW (1969) Investigating causal relations by econometric models and cross-spectral methods. Econometrica pp 424–438
Granger CW (1980) Testing for causality: a personal viewpoint. Journal of Economic Dynamics and Control 2:329–352
Greif A, Laitin DD (2004) A theory of endogenous institutional change. American Political Science Review 98(04):633–652
Haavelmo T (1944) The probability approach in econometrics. Econometrica: Journal of the Econometric Society pp iii–115
Harrod RF (1939) An essay in dynamic theory. The Economic Journal pp 14–33
von Hayek FA (1937) Economics and knowledge. Economica pp 33–54
von Hayek FA (1945) The use of knowledge in society. The American economic review 35:519–530
von Hayek FA (2008 [1931]) Prices and Production and Other Works. Ludwig von Mises Institute, Auburn, Ala.
Hempel CG (1942) The function of general laws in history. The Journal of Philosophy pp 35–48

Hughes TP (1983) Networks of Power: Electrification in Western Society, 1880-1930. The John Hopkins University Press, Baltimore
Hughes TP (1987) The evolution of large technological systems. In: Bijker WE, Hughes TP, Pinch TJ (eds) The social construction of technological systems : new directions in the sociology and history of technology, MIT press, Cambridge, Mass., pp 51–82
Hulswit M (2006) How causal is downward causation? Journal for General Philosophy of Science 36(2):261–287
Hume D (2011 [1748]) An enquiry concerning human understanding. Broadview Press
Hume D (2012 [1738]) A treatise of human nature. Courier Dover Publications
Kaldor N (1972) The irrelevance of equilibrium economics. Economic Journal 74:pp. 541–547
Kaldor N (1981) The role of increasing returns, technical progress and cumulative causation in the theory of international trade and economic growth. Economie appliquée 34(6):593–617
Kalecki M (1939) Essays in the Theory of Economic Fluctuations. Allen and Unwin, London
Krugman P (1996) The Self-Organizing Economy. Malden, MA: Blackwell Publishers Ltd
Kuhn TS (2012 [1962]) The Structure of Scientific Revolutions. University of Chicago press
Lawson T (1989) Realism and instrumentalism in the development of econometrics. Oxford Economic Papers 41(1):236–258
Lewis D (1973) Causation. The Journal of Philosophy pp 556–567
Lipsey RG, Carlaw K, Bekar C (2005) Economic transformations : general purpose technologies and long term economic growth. Oxford University Press, New York
Mandel E (1975) Late Capitalism, trans. New Left Books, London
Marshall A (2009) Principles of Economics (eighth edition). Cosimo, Inc.
Marx K (1991 [1894]) Capital: A Critique of Political Economy, Volume III. Penguin Books, London
Marx K, Engels F (2001 [1885]) The 18th Brumaire of Louis Bonaparte. Electric Book Co., London
McNerney J, Fath BD, Silverberg G (2013) Network structure of inter-industry flows. Physica A: Statistical Mechanics and its Applications 392(24):pp. 6427–6441
Meyer JR, Conrad AH (1957) Economic theory, statistical inference, and economic history. The Journal of Economic History 17(04):524–544
Mill JS (2011 [1843]) A System of Logic, Ratiocinative and Inductive: Being a Connected View of the Principles of Evidence, and the Methods of Scientific Investigation Volume 1. Cambridge University Press, Cambridge
Mjøset L (1994) Johan Åkerman. In: Hodgson G, Tool M, Samuels WJ (eds) Handbook on Institutional and Evolutionary Economics, Edward Elgar, Aldershot, pp 9–11
Moneta A (2005) Causality in macroeconometrics: some considerations about reductionism and realism. Journal of Economic Methodology 12(3):433–453
Nelson RR, Winter SG (1982) An evolutionary theory of economic change. Harvard University Press, Cambridge, Mass.

North DC (1978) Comment on McCloskey, Cohen, and Forster Papers. Journal of Economic History pp 77–80
North DC (1991) Institutions. Journal of Economic Perspectives 5(1):97–112
Nyblén G (1949) Atomistisk och holistisk ekonomisk teori. Ekonomisk Tidskrift pp 258–282
Pålsson Syll L (1997) Utility Theory and Structural Analysis. Essays in the History of Swedish Economic Thought. PhD thesis, Lund University
Popper K (2002 [1935]) The Logic of Scientific Discovery. Routledge, London
Popper K (2010 [1945]) The Open Society and its Enemies. Routledge, London
Robinson J (1962) Essays in the theory of economic growth. Macmillan
Robinson J (1980) Time in economic theory. Kyklos 33(2):pp. 219–229
Rosenberg N (1969) The direction of technological change: inducement mechanisms and focusing devices. Economic Development and Cultural Change 18(1):1–24
Russell B (1912) On the notion of cause. Proceedings of the Aristotelian society pp 1–26
Schön L (1991) Development blocks and transformation pressure in a macroeconomic perspective - a model of long-term cyclical change. Skandinaviska Enskilda Banken Quarterly Review XX(3-4):67–76
Schön L (1994) Långtidsutredningen 1995. Bil. 3, Omvandling och obalans : mönster i svensk ekonomisk utveckling. Fritze, Stockholm
Schön L (1998) Industrial crises in a model of long cycles: Sweden in an international perspective. In: Myllyntaus T (ed) Economic Crises and Restructuring in History, Scripta Mercaturae Verlag, Katharinen, pp 396–413
Schön L (2010) Sweden's Road to Modernity: An Economic History. SNS förlag, Stockholm
Schumpeter JA (1911) Theorie der wirtschaftlichen Entwicklung. English translation: The theory of economic development. Harvard, 1934, Eight printing, 1968, Harvard University Press, Cambridge, Massachusetts. Cambridge, MA: Harvard University Press
Schumpeter JA (1947) The creative response in economic history. The journal of economic history 7(2):pp. 149–159
Simon HA (1953) Causal Order and Identifiability. In: Studies in Econometric Method, Yale University Press, New Haven, pp 49–74
Simon HA, Rescher N (1966) Cause and counterfactual. Philosophy of Science pp 323–340
Stieglitz N, Heine K (2007) Innovations and the role of complementarities in a strategic theory of the firm. Strategic Management Journal 28(1):pp. 1–15
Taalbi J (2014) Innovation as Creative Response: A Study of the Determinants of Innovation in the Swedish Manufacturing Industry, 1970-2007. School of Economics and Management, Department of Economic History, Lund University, Lund
Wittgenstein L (2001 [1922]) Tractatus logico philosophicus. Routledge, London
Young AA (1928) Increasing returns and economic progress. The Economic Journal pp 527–542