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Functions and mechanisms in structural-modelling explanation

WUNSCH, G., MOUCHART, M. and F. RUSSO

Functions and Mechanisms in Structural-Modelling Explanations

Guillaume WUNSCH [a], Michel MOUCHART [b], Federica RUSSO [c]

[a] *Demography, Université catholique de Louvain, Belgium*

[b] *CORE & ISBA, Université catholique de Louvain, Belgium*

[c] *Center Leo Apostel, Vrije Universiteit Brussel, Belgium and & Centre for Reasoning, University of Kent, UK*

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Abstract

One way the social scientists explain phenomena is by building structural models. These models are explanatory insofar as they manage to perform a recursive decomposition on an initial multivariate probability distribution, which can be interpreted as a mechanism. The social scientists should include the variables in the model on the basis of their function in the mechanism. This paper examines the notion of 'function' within structural modelling. We argue that 'functions' ought to be understood as the theoretical underpinnings of the causes, namely as the role that causes play in the functioning of the mechanism.

Keywords: Causality; Explanation; Function; Mechanism; Recursive Decomposition; Structural Modelling.

Contents

1 Introduction

Social scientists study a variety of phenomena both at the group and at the individual level. One difficulty social scientists face, however, is that their object of investigations—human beings and their behaviour—can be very heterogeneous across time, across cultures, or across geographic regions.

Consider for instance alcohol consumption. Balt people drank, in the former USSR, because drinking relieved stress. British people drink to socialise. Mediterraneans drink to accompany a lavish meal, although binge drinking is becoming more and more popular across young people. Alcohol consumption, it seems, has different functions in different places. Drinking has, ceteris paribus, the same health effects, but also different 'social' reasons and effects. Surely we can understand drinking behaviours if we find out the societal function of drinking.

According to an established tradition in social science and in philosophy, to explain a phenomenon we need to invoke the causes that bring it about. Recent debates have shown that, arguably, in order to explain a phenomenon we need more than to invoke the causes. We need to provide a (plausible) mechanism for the phenomenon (Hedström and Swedberg 1998, Demeulenaere 2011a). Structural models in social science are in this tradition. Social scientists use structural models to explain phenomena and these models are explanatory insofar as they model a mechanism. From a methodological point of view, the bulk of a 'structural-modelling explanation' is the concept of recursive decomposition. This means breaking down an initial joint probability distribution into simpler parts, namely the marginal and conditional components, such that exogenous variables can be explicitly interpreted as causes (see section 2.2.2).

However, we need to go further. Besides modelling the mechanism and identifying the relevant causes acting in it, we also have to say *why* some (causal) variables have been chosen instead of some others. Intuitively, this amounts to spelling out the *function*, or role, these variables play in the mechanism. The paper examines the role of 'function' in structural-modelling explanations.

The paper is organised as follows. Section 2 presents structural-modelling explanations, with particular attention to the recursive decomposition and to the overall model building and model testing methodology. Section 3 considers the relation between mechanisms and explanation and prepares the ground for the discussion of the concept of function in section 4. In particular, we endorse an epistemic view of explanation, according to which it is the *description* (of the functioning) of the mechanism that does the explaining job. We also show why the recursive decomposition may be interpreted as a (social) mechanism. Finally, in section 4 we examine two accounts of 'function': in terms of 'role-function' and 'isolated descriptions' and in terms of 'functional architecture'. We argue that modelling a mechanism requires individuating both the function of the mechanism and of its components. This is done throughout the modelling procedure by providing the theoretical underpinnings, *i.e.* the functions of the chosen causal factors.

2 Structural-modelling explanations

Structural models, in a broad sense, are widely used in current social science practice. The details of the *meaning* of 'structural' or of the specific technical characteristics may vary among different schools of thought and authors. In this section we trace the main lines of the origins of structural models, in order to introduce the approach that we endorse in this paper. Such an overview will also set the ground for presenting the conceptual links between structural models and explanation through the recursive decomposition.

2.1 Structural models: origins

In econometrics, the members of the Cowles Commission, in particular Koopmans (1950a) and Hood and Koopmans (1953), developed a concept of structural model under the motto 'no measurement without theory' (Koopmans 1947). They proposed to start with a set of equations generated by economic theory, the latter implying which variables should be considered as globally exogenous and the other ones being named endogenous. These equations form a system of simultaneous equations qualified as 'structural', with the aim of representing an economic structure. From this structural model they deduced the joint distribution of the endogenous variables conditionally on the exogenous variables and called this model the 'reduced form' (Koopmans 1950b). They analysed a substantial issue of identification of the structural parametrization and pointed out that economic theory should provide restrictions necessary to ensure the identification of the structural parameters (Koopmans 1953). Economic theory also imposes restrictions (named 'over-identification') on the parameters of the reduced form. Briefly, in this approach economic theory is the basis for constructing and identifying the structural model and is also used to improve statistical inference thanks to over-identifying restrictions.

Among many contributions, Herman Wold (1949, 1954) followed up the Cowles Commission works on simultaneous equations in the direction of a recursive decomposition; his purpose was to disentangle the simultaneity of a system of structural equations. He argued that economic theory should provide a naturally recursive system but that simultaneity may derive from incomplete observability of the behaviour of the system. Further developments in simultaneous equation models led Wold and his collaborators to develop a class of models close to the structural models of other social sciences.

Another origin of structural modelling is rooted in the path analytic methodology developed by Sewall Wright and in the subsequent causal models for non-experimental research—from the 1960s and 1970s—of Blalock, Duncan, and Boudon, among others. In a series of papers published from 1918 onwards, Sewall Wright developed the methodology of *path analysis* for measuring causal relations. He represented these relations in branching sequential order (*i.e.* as a recursive system) by an arrow-diagram, a graphic representation taken up much later and expanded by Judea Pearl especially, in his directed acyclic graphs (DAG) approach to causality (Pearl, 2000). Wright (1934, p. 175) took pains in stressing the fact that his path analytic model should be based on "such information as may be at hand with regard to causal relations", thus making the model dependent upon background knowledge, unlike data mining or exploratory data analysis.

The issue that the starting point of causal modelling is "a firm grasp of the relevant scientific theory", and not the statistical methods actually employed, is also highlighted by Otis Dudley Duncan (1975, p. 6) in his application of structural equation modelling to sociological data. Hubert M. Blalock too was instrumental in linking theory and empirical research in the social sciences by the use of causal models, though he insisted that

> we can never actually demonstrate causal laws empirically. This is true even where experimentation is possible. Causal laws are working assumptions of the scientist, involving hypothetical statements of the *if-then* variety. Included among the *if's* of causal assertions is the supposition that all relevant variables have been controlled or can safely be ignored. This kind of assumption can never be tested empirically (Blalock, 1964, pp. 172-173).

Raymond Boudon (1967) took the same stance that statistics alone cannot lead to establishing causal relations in the absence of a causal interpretation. Causal claims always relate to the causal model that is proposed. His "dependency analysis" of causal structures was influential in introducing the American structural modelling approach and causal diagrams (actually DAGs) to the French-speaking social scientists.

2.2 From structural models to explanation

2.2.1 Structural models: a further development

We develop an account of *how* a structural model has to be built in order to explain phenomena, and to do so employs a recursive decomposition, as explained in section 2.2.2. In particular, we stress the role of the recursive decomposition: a recursive decomposition explains insofar as it is interpretable as a mechanism (see also Mouchart, Russo, Wunsch 2010).

Following in the footsteps of the father-figures of social science methodology (*e.g.* Blalock), we depart from the Cowles Commission tradition in that we enlarge the role of theory to the wider concept of background knowledge as follows. First, the structural modeller does not restrict background knowledge to economic theory or to any other particular theory, but s/he takes into account all relevant information; second, the structural modeller navigates among plausible specifications of the model, guided by invariance considerations across specified changes of the environment. As a consequence, building a structural model is a more complex issue than just a statistical translation of a pre-specified theory.

However, in contradistinction to the models based on a system of (linear) *equations* that are at the basis of most of the works of the father-figures of social science methodology, we develop a general presentation of structural modelling in terms of probability *distributions* and (conditional) recursive decomposition of the data set. Switching from equations to distributions is important for two reasons:

(i) Writing an equation endowed with a residual term does not make statistical meaning unless it is completed with additional specifications providing a precise interpretation in terms of the implied conditional distributions. For instance, in the literature on econometric simultaneous equation systems, it has been crucial to understand that a structural equation does not represent a conditional expectation (see *e.g.* Fennell 2011). Moreover, a cause may have a more substantial effect on the conditional variance or on the conditional tails then on the conditional expectation (see *e.g.* Heckman 2008).

(ii) Important issues in structural modelling concern not only the ordering of the variables in view of obtaining a suitable recursive decomposition, but also condensing conditional distributions by means of conditional independence restrictions. The concept of conditional independence cannot be fully expressed in terms of (structural) equations. In other words, the relationship $X \perp\!\!\!\perp Y | Z$ is *equivalently* written as $f(x) \perp\!\!\!\perp g(y) | h(z)$ for any one to one (injective) functions f, g, h. Mathematically speaking, this calls for a σ-algebraic approach rather than for a Hilbert-space approach.

We restrict the present discussion to recursive systems without reciprocal or two-way causation. As other social scientists have done (see *e.g.* Morgan and Winship, 2007, chapter 8), we defend the view that causal explanations require modelling a plausible mechanism for the data generating process. In this perspective, the condensed recursive decomposition can be interpreted as a mechanism (see later section 2.2.2). In addition, the whole mechanism, and each of its components (or sub-mechanisms), must have a specified function. Furthermore, we stress that the characteristics of the structural model should be stable in a given context, in order to reach explanatory generalisations. Our structural modelling approach is not rooted to a counterfactual/manipulationist basis, though it is not in contradiction with the latter: counterfactuals and interventions can indeed be useful tools for assessing causal relations (see for instance Russo, Wunsch, Mouchart 2011).

We also develop a peculiar meaning of 'structural', that departs from other scholars' use in the current debates. The accounts proposed by *e.g.* Woodward (2003, ch.7), Pearl (2011), or Hoover (2011) do not take issue *specifically* with what 'structural' means and do not spell out the conceptual underpinnings of the recursive decomposition in terms of mechanistic explanation. The contributions of the above-mentioned authors confine the discussion of their concept of structural modelling (i) to the relation with the notion of invariance under intervention (Woodward), or (ii) as a general methodological framework able to subsume, as special cases, particular models such as structural equation models, potential outcome models, and graphical models (Pearl), or (iii) to relations with the notion of causal ordering developed by Herbert Simon (Hoover). For a discussion, see Russo (2011a).

2.2.2 Structural models: explaining through the recursive decomposition

In the context of quantitative analysis, our perspective starts from statistical models made of a typically—but not always—parametrized family of distributions generated by a set of plausible hypotheses; these suggest how the observations under analysis may have been produced by the so-called data generating process (DGP).

Formally, this model involves a systematic and a stochastic aspect. The systematic aspect aims at representing what is explained by the model whereas the stochastic component stands for what is not explained by the model. Modelling the specific pattern underlying the data generating process requires taking into account the contextual knowledge of the field of application. A structural model should accordingly help understand the data generating process; more precisely, its characteristics, or parameters, should be interpretable. Moreover a structural model should be stable, or invariant, across changes of the environment. We use 'invariance' and 'stability' interchangeably.

The complexity of the social world typically leads to a multidimensional approach. Understanding such complex phenomena requires introducing structure into the model and this can be achieved by operating an ordered decomposition of the multivariate distributions of the variables. In other words, explaining involves breaking down a complex phenomenon into simpler parts. This decomposition of the data generating process is operationalised by a systematic *marginal-conditional decomposition* as follows.

More precisely, let us consider a decomposition of data set X into p components such as $X = (X_1, X_2, \cdots X_p)$. Suppose that the components of X have been ordered in such a way that in the complete marginal-conditional decomposition

$$\begin{aligned} p_X(x \mid \omega) \quad = \quad & p_{X_p \mid X_1, X_2, \cdots X_{p-1}}(x_p \mid x_1, x_2, \cdots x_{p-1}, \theta_{p \mid 1, \cdots p-1}) \\ & \cdot p_{X_{p-1} \mid X_1, X_2, \cdots X_{p-2}}(x_{p-1} \mid x_1, x_2, \cdots x_{p-2}, \theta_{p-1 \mid 1, \cdots p-2}) \cdots \\ & \cdot p_{X_j \mid X_1, X_2, \cdots X_{j-1}}(x_j \mid x_1, x_2, \cdots x_{j-1}, \theta_{j \mid 1, \cdots j-1}) \cdots p_{X_1}(x_1 \mid \theta_1), \end{aligned} \tag{1}$$

where $\theta_{j|1,\cdots j-1}$ stands for the parameter characterising the conditional distribution of $(X_j \mid X_1, X_2, \cdots X_{j-1})$, the factors of the right hand side of (1) have mutually independent parameters, *i.e.* in a sampling theory framework:

$$\omega = (\theta_{p|1,\cdots p-1}, \theta_{p-1|1,\cdots p-2} \cdots, \theta_1) \in \Theta_{p|1,\cdots p-1} \times \Theta_{p-1|1,\cdots p-2} \cdots \times \Theta_1. \quad (2)$$

Condition (2) excludes restrictions among parameters of different factors of the r.h.s.; in particular common parameters of different factors are not allowed. Under the condition (2), the decomposition (1) is called a *recursive decomposition.*

Once the number p of components increases, background knowledge, substantiated by analysis of the data and statistical tests, can provide a simplification of the factors in the form of conditional independence properties. More specifically, it is typically the case that the distribution of $(X_j \mid X_1, \cdots, X_{j-1})$ is known not to depend on some of the conditioning variables. Thus there is a subset $\mathcal{I}_j \subset \{X_1, \cdots, X_{j-1}\}$ of variables whose actual relevance for the conditional process generating $X_j \mid X_1, \cdots, X_{j-1}$ is defined by the property

$$X_j \perp\!\!\!\perp X_1, \cdots, X_{j-1} \mid \mathcal{I}_j, \theta. \quad (3)$$

This property implies that the factor $p_{X_j|X_1,X_2,\cdots X_{j-1}}$ in (1) is actually simplified into $p_{X_j|\mathcal{I}_j}$ and $\mathcal{I}_j$ may be called the *relevant information of the j-th factor.* Once $\mathcal{I}_j$ has been specified for each factor, (1) is condensed into

$$p_{X_1,X_2,\cdots X_p|\theta} = \prod_{1\leq j\leq p} p_{X_j|\mathcal{I}_j,\theta_{j|1,\cdots j-1}} \quad (4)$$

This form will be called a *condensed recursive decomposition.*

The goal of structural modelling is to characterise, as much as possible, clearly identified and interpretable sub-mechanisms of the global mechanism. More specifically, equations (4) and (2) represent a global mechanism; its factors, given by the conditional distributions, are to be interpreted as sub-mechanisms (Mouchart and Russo (2011)). The choice of the marginal-conditional decomposition is therefore not arbitrary; we need background knowledge and invariance to select one among the p! possible decompositions. In other words, the marginal-conditional decomposition *alone* does not provide a (causal) explanation of a given phenomenon, but the whole modelling procedure does (Russo 2011b).

A crucial aspect of the multiplicative structure (4) under the condition (2) is to allow an inference on the parameters of interest, namely functions of $\theta_{j|1,\cdots j-1}$, *independently* of the specification of the process that generates the conditioning variables, provided only that condition (2) is satisfied. This is accordingly a condition of separation of inferences. In other words, the parameters of interest should only depend upon the parameters identified by the conditional model and the parameters identified by the marginal process should be "independent" of the parameters identified by the conditional process. In this case, the conditioning variables of each conditional component of the decomposition are *exogenous* variables (for details, see Koopmans (1950b), Florens, Mouchart and Rolin (1980), Engle, Hendry and Richard (1983), Florens and Mouchart (1985)).

Mouchart, Russo and Wunsch (2009) argue that *causes* may then be viewed as exogenous variables in the condensed recursive decomposition, alternatively as the relevant information of a structurally valid conditional distribution. Thus the variation-free condition (2) does not only allow us to separate the inferences on $\theta_{j|1,\cdots,j-1}$ and on $\theta_{1,\cdots,j-1}$, but it also allows us to distinguish the process generating the causes, characterised by $\theta_{1,\cdots,j-1}$, and the process generating the effects, characterised by $\theta_{j|1,\cdots,j-1}$. Separating causes from effects mirrors the asymmetry of causation. Associating each component of the condensed recursive decomposition with a sub-mechanism of the data generating process provides interpretability to the parameters of the corresponding conditional distributions. Readers familiar with the literature on graph models may recognise that a directed acyclic graph (DAG) is a simplified graphic representation of a condensed recursive decomposition and that the causal structure is depicted by the set of ancestors. This simplification may not be suitable to complex situations.

Why interpreting *exogenous* variables as *causal* factors? The reason is that, as we discussed earlier, structural modelling aims to explain a complex phenomenon. In turn, to explain a complex phenomenon, we need to model 'structures', namely mechanisms where the acting parts are interpreted as causes. The philosophical underpinnings of such an approach are the following:

(i) Explanation, at least in the social contexts we are concerned with, is *mechanistic* explanation. (Notice that mechanisms need not be deterministic. In a structural modelling framework, mechanisms are, rather, stochastic.)

(ii) Mechanistic explanation is successful insofar as the *functioning* of the mechanism is properly spelled out.

(iii) Spelling out the functioning of the mechanism amounts to identifying the *causes*, their actions, and their effects.

In section 3 and 4 we spell out these philosophical underpinnings.

3 Explanation and mechanisms

We mentioned earlier that a structural model explains insofar as it models a (plausible) mechanism for the phenomenon of interest. But how is this relation between explanation and mechanisms to be understood? In this section we give some background of how this issue has been addressed in the literature and of how it is addressed in the context of structural explanations.

3.1 Why mechanisms explain

The recent and rapidly expanding literature on mechanisms is working simultaneously on two (inter-related) fronts. On the one hand, mechanists (*i.e.* scholars working in the philosophy of mechanism) work towards a definition of what a mechanism is. On the other hand, they also work towards spelling out the explanatory import of mechanisms. These two issues are of course related.

Several definitions of 'mechanism' have been proposed in the literature (Machamer *et al.* (2000); Glennan (2002); Bechtel and Abrahamsen (2005); Franck (see section 4.2)). We embrace the one recently given by Illari and Williamson (2012):

> A mechanism for a phenomenon is composed of entities and activities organized so that they are responsible for the phenomenon.

Illari and Williamson offer several arguments to say that their definition constitutes a potential 'consensus'. We lack space to thoroughly discuss why we agree with Illari and Williamson that it represents a consensus definition. It will suffice to say that this definition is general enough to be applied to social contexts, besides biology or neuroscience (the main subject fields in which the mechanism debate takes place). It is also worth mentioning that Illari and Williamson's definition still hinges (as indeed the other definitions did) upon the 'entity-activity' ontology and stresses the importance of the organisation of the mechanisms. We shall see later in section 4 why these components (entity-activity and organisation) are important in order to understand the concept of 'function' in structural explanations. Another reason for our choice is that Illari and Williamson do not define mechanisms in terms of manipulation or counterfactuals.

It is worth noting that the philosophical literature on mechanisms originated from (and to some extent still draws on) paradigmatic examples of mechanisms in biology or neuroscience. Comparatively less attention has been paid to social mechanisms. Thus, by extending the arguments developed for biological or psychological mechanisms, we also endeavour to bring social mechanisms into this philosophical debate.

A detailed discussion of social mechanisms, from the viewpoint of analytical sociology especially, can be found in a volume edited a few years ago by Hedström and Swedberg (1998), on which the following is partly based. Little (1991, 2011) also offers a discussion of social mechanisms drawing on examples from various social science disciplines. As mentioned in the definition above, generally speaking, a mechanism is conceived of a set of interacting parts or elements organised in such a way that it produces or generates an effect. Following this line of reasoning, a social mechanism is then a plausible account of how change in social processes is brought about through sequences of cause and effect relations. We look for mechanisms in order to increase our understanding of the observed joint variations between variables of interest and to possibly intervene with policy actions at the right point of the mechanism (Russo, 2009).

Many social mechanisms are rooted in the principle of methodological individualism, *i.e.* in the behaviours of individuals. They can relate to the interactions among individuals (micro-micro effects), to the impact of social institutions and contexts on individual behaviours (macro-micro effects), or to the consequences of individual actions on the macro level (micro-macro effects). From this viewpoint, all macro-macro effects should be explained by the actions of individuals: there would be no such thing as macro-level mechanisms (for an opposite view, see however Ylikoski 2011). Social mechanisms are of course unobserved analytical constructs that propose hypothetical causal links between observed events. As stressed *e.g.* by Diego Gambetta (1998), we hypothesise social mechanisms but we cannot observe them directly. This is indeed what the recursive decomposition discussed in section 2.2.2 is supposed to do: to model data generating processes in terms of mechanisms. We can however test mechanisms via their predicted effects, *i.e.* by comparing implications of the mechanisms with empirical facts.

It is worth noting that we are not just saying that there *is* a data generating process or data generating mechanism that 'produces' the data. *Modelling* the data generating process precisely means to specify what this mechanism is. The causal structure modelled in the recursive decomposition is meant to open the black box—to the best of our knowledge—namely it aims to explain associations between variables by plausible cause and effect relations generating these associations. An association between two variables such as occupation and fertility could indeed be explained by a causal effect of occupation on fertility, by the reverse relation of fertility affecting occupation, or by the impact of a third variable, such as education, that could have an effect on both occupation and fertility. The mechanism should in this case specify, if possible, which of these causal relations is (or are) at the origin of the association observed. In other words, a social mechanism is an explanation of how change in an outcome variable, or a set of outcome variables, is brought about, and in this sense it is also a description of the *functioning* of the mechanism. Such an explanation should display a suitable level of stability in order to reach some level of explanatory generalisation.

From the point of view of structural-modelling explanations there are two aspects that need to be discussed. The first is modelling social mechanisms by means of the recursive decomposition, which has been detailed earlier in section 2.2.2. The second is the function that the mechanism and that its elements play in the explanation. This is undertaken later in section 4.

3.2 Social mechanisms as recursive decompositions

The bulk of a structural explanation is the recursive decomposition. This amounts to breaking down an initial multivariate probability distribution into 'smaller pieces'. We say that the whole recursive decomposition represents the global mechanism, whereas the smaller pieces represent the sub-mechanisms.

For instance, Gaumé and Wunsch (2010) carry out a study on the determinants of subjective health in the Baltic States for the period 1994-1999 and offer a mechanism, based on background knowledge, that explains subjective health by a series of possible individual determinants and their interrelations. The global mechanism explaining subjective health has sub-mechanisms. For instance, the impact of alcohol consumption on subjective health depends upon educational level of the individual, physical health status, level of psychological distress. These items themselves depend upon other factors that are part of the global mechanism; for example, psychological distress is influenced by the individual's locus of control and social support. A number of remarks are in order.

First, *different* mechanisms may explain a same phenomenon. For example, abortion might not be performed for ideological reasons (*e.g.* among Roman Catholics) or because it is illegal (*e.g.* in Romania in Ceauşescu's time).

Second, not all mechanisms can be represented by a recursive decomposition. For instance, we doubt that the mechanism for photosynthesis can be represented in terms of a recursive decomposition. We do not claim either that all social mechanisms can be represented by recursive decomposition, due to a contingent lack of information. For example, Mouchart and Vandresse (2007) analyse data on a set of commercial contracts, each one characterised by a price and some characteristics of the contract and claim that knowing only the contract resulting from negotiations does not provide sufficient information for deciding which of the characteristics or the price were firstly decided upon, the most likely hypothesis being that each contract was concluded after several rounds of negotiations. The presence of latent (*i.e.* unobserved) variables may also play havoc with the results of the structural model.

Yet, *if* we had complete information we would be indeed in a position to fully explain the phenomenon by a recursive decomposition. In other words the recursive decomposition *may* be interpreted as a mechanism. But it is not the mechanism that does the explaining. It is the whole modelling procedure including the reasons for choosing some variables rather than others. Differently put, explaining a social phenomenon also involves specifying the reasons, or functions, of the causes. It is of course an open question how far a social mechanism can be recursively decomposed. In a systemic approach, where directed causal relations are replaced with multi-directed influence relations, recursivity would not be satisfied. This may indeed be a more faithful description of reality, but not necessarily a useful modelling strategy for explanation or intervention (see Russo 2010).

Third, not all models are explanatory, *i.e.* not all models in social science have to be structural. A good example are population projection models. Simplified models based on associations only can lead to better results than other more sophisticated ones. This of course opens Pandora's box concerning the relations between explanation, prediction and background knowledge. But we keep this box firmly closed in this paper.

4 Functions and mechanisms

It should be noted that the mechanism/functions view developed in this paper should not be confused with the much broader functionalist perspective *à la* Radcliffe-Brown or Malinowski, where every social practice in a society must have (or must have had) a function in the society as a whole. This originates in the works of Durkheim and Mauss, and has been further developed by Parsons and Merton. In our case, the concept of function is restricted to a particular mechanism and to its components, proposed for modelling a specific data generating process—we deal with this issue later in section section 4.3.

In the previous sections, we recalled the core idea behind structural-modelling explanations: causal models explain insofar as (i) they are able to perform a recursive decomposition and (ii) this decomposition can be interpreted as a (social) mechanism. We stressed the importance of background knowledge to choose the variables and relations to include in the model. This amounts, to anticipate the arguments that will be developed in detail later, to specify the *function*, or role, or reason, played by such variables.

Function is however a philosophically loaded notion, on which debate is still vivid. We isolate two discussions of functions that are of interest to our purposes. The first is Illari and Williamson's discussion of function and organisation in mechanisms. The second is Franck's treatment of functions, which relies on the notion of 'functional architecture'. Both discussions help us clarify our position, that we present in section 4.3.

4.1 Role-functions and isolated descriptions

The recent philosophical literature on mechanisms agrees that the individuation of the function of the mechanisms is important. Functional individuation has however a 'double' facet. One is the *function of the mechanism* itself, namely what is the mechanism for. The other is the *function of the components of the mechanism*. Illari and Williamson (2010 p.283) say:

> The relevant sense in which a mechanism as a whole has a function depends on whether the mechanism is situated in a context, or considered alone. If it is situated in a context, then it can have a role-function. The mechanism for the pumping of the heart, for example, might itself have a role-function. This is so if that mechanism is to be understood within the context of explaining the circulation of the blood. That itself might further be understood in the context of keeping the animal alive, and so on. But if there is no reference to a containing system, a mechanism has only an isolated description, or characteristic activity. This is where functional descriptions top out.

This is the case in social contexts too. For example, alcohol consumption can have a role-function in the process of socialisation, itself a factor conducive to an individual's social well-being.

But alcohol intake can also have a detrimental impact on physical and mental health, and is thus an important determinant of morbidity and mortality. A same behaviour can thus play different roles in different mechanisms.

Illari and Williamson (2010) then argue that these two aspects (the function of the mechanism and the function of the components of the mechanism) are best cashed out by views developed by Cummins and by Craver: functions are to be understood as 'role-functions' (Cummins 1975) and as 'isolated descriptions' (Craver 2001). Let us examine these in turn.

The function of the mechanism. Cummins (1975) develops the concept of 'role-function': the function of something is the role it plays in the overall behaviour (Cummins 1975, p. 762):

> x functions as a ϕ (or, the function of x in s is to ϕ) relative to an analytical account A of s's capacity to ψ just in case x is capable of ϕing in s and A appropriately and adequately accounts for s's capacity to ψ by, in part, appealing to the capacity of x to ϕ in s.

This way of identifying the role-function of a mechanism happens in the kind of explanatory contexts we have been considering in this paper. In fact, structural-modelling explanation begins with the identification of the research question. For instance, suppose we observe a fall in fertility in Europe. Research would accordingly turn to the determinants of the fertility decrease. A structural-modelling explanation would then build a model in order to account for such a phenomenon. Such a model would be explanatory insofar as it represents a (plausible) mechanism of the fall of fertility. This would be the (role-)function of the mechanism. Functional individuation does not stop here, however. The components of a mechanism have themselves a role in the production of the phenomenon. This aspect is discussed below.

The function of the mechanism can be also understood in terms of Craver's concept of 'isolated description'. For Craver, the function of a mechanism or of a component of it can be picked out in a contextual way or in a more isolated way (Craver 2001, p. 65):

> But this leaves it ambiguous whether the function is the capacity, described in isolation and simply 'picked out' by its contextual role, or, instead, the contextual role by virtue of which the capacity is picked out. A complete description of an item's role would describe each of these . . . There is a difference, after all, between knowing that spark plugs produce sparks and knowing how that sparking is situated within the complex mechanisms of an engine.

This is indeed very akin to Cummin's role-function discussed above. In the end, the issue is to understand which mechanism can account for the phenomenon we are interested in. This aspect, that mechanisms are always 'mechanisms *for* a phenomenon', has been emphasised by Stuart Glennan as early as 1996.

The function of the components of the mechanism To understand the functioning of a mechanism, we must understand what its components do, namely what their function is. To give a brief example, in the Baltic countries in the early nineties (Gaumé and Wunsch, 2010), alcohol consumption had an impact on self-rated health, but its function or role (*i.e.* *why* Balts drink) seemed to lie in its stress-reducing and possibly in its socialization effects. In other contexts, however, this stress-reducing role could be implemented by other empirical behaviours such as ritual dances, meditation, taking drugs, and so on, and the socialization role by attending church, participating in social and political activities, *etc.* According to the context, the same function can be implemented by different causes.

Here, the relevant concept of function is, again, Cummin's role-function. In fact, the task is to understand the role played by the components of the mechanism in order to produce the behaviour under examination. Illari and Williamson (2010, p. 285) explain this idea thus:

> Activities [*i.e.* what parts of mechanism do] are interesting because they often are the functions of the entities—an activity is what an entity does, or what two or more entities do together. Activities are individuated in a similar way to entities in the hierarchy of mechanisms. Activities are identified in terms of their contribution to the behaviour of the phenomenon to be explained.

Structural-modelling explanation considered in this paper works in the same way. Although structural-modelling explanation does not make explicit use of the concept of 'activity', this does not create a contradiction. Functional individuation, according to Illari and Williamson, also includes specifying what the components of the mechanism (the entities) do (the activities). Structural-modelling explanation operates an analogous functional individuation too. In structural modelling, the identification of the components of the mechanisms and of their role-function is done through the recursive decomposition, as explained earlier in section 2.

4.2 Functional architectures

In his work, Robert Franck (1994, 1995, 2002, 2007) has stressed the role of the functional architecture of mechanisms. Franck (2002, p. 295) summarises his approach as follows:

> (1) Beginning with the systematic observation of certain properties of a given social system, (2) we infer the formal (conceptual) structure which is implied by those properties. (3) This formal structure, in turn, guides our study of the social mechanism which gen-

erates the observed properties. (4) The mechanism, once identified, either confirms the advanced formal structure, or indicates that we need to revise it.

Franck continues by stating that the role of empirical research is to describe and to analyse the properties of the social system under study. From these properties, a conceptual or theoretical structure is inferred, on the basis of the principles or functions putatively governing the properties. This inferred formal structure guides the investigation of the empirical mechanism generating the properties, *i.e.* it suggests possible empirical factors contributing to the outcome. Finally, the empirical mechanism confirms or disconfirms the value of the theory proposed.

Franck thus distinguishes between the theoretical functional structure proposed after examining the properties of the social process under study, and the empirical mechanism actually generating them. In other words, the theoretical model or functional architecture is not tied to a particular empirical mechanism—even though it is derived from empirical observations—and can be transferred to other social processes with similar properties, the theoretical properties or functions being possibly implemented by different functionally equivalent empirical means or causes and by their combination. It is however the functional architecture that is necessary to produce the social process and not the empirical mechanism (such as a causal model), which is contingent upon the context. In this sense, the functional architecture is to some extent generalizable while the empirical mechanism is not.

4.3 Functions in structural explanations

The discussion of Illari and Williamson and the approach of Franck set the ground for us to say how functions ought to be understood in the context of structural-modelling explanation. The meaning of function as 'role-function' and its importance for model building are pretty easily established. More debatable is instead the move of giving more importance to functions than to causes and thus privileging the 'functional architecture' over the 'causal architecture'. A large part of this section is devoted to clarifying similarities and divergences with Franck's account. We close the section with a note on the relation between structural and functional explanation.

Functions in structural explanations are role-functions. We agree with Illari and Williamson that role-functions are important for structural explanation. The concept of role-function, applied both to the mechanism as a whole and to its components, cashes out the meaning of function in the context we are interested in.

Structural explanations performed by recursive decomposition involve a global mechanism and organised sub-mechanisms. Such sub-mechanisms have role-functions too. In this approach, a conditional distribution is interpreted as a mechanism provided that it is supported by background knowledge. If the recursive decomposition has been suitably condensed, a conditioning variable in a mechanism affects the characteristics of the conditional distribution, such as the conditional expectation or variance, the fractiles or the tail of the conditional distribution *etc.* This reflects the role or function of the conceptual variable in the mechanism.

Functions, to be more precise, are the reasons why we choose some variables and relations rather than others. Thus, functions *already* belong to the hypothetico-deductive methodology of structural-modelling explanation. In other words, they are not *new* elements; they are instead the theoretical underpinning of causes. Identifying the functions in a structural model means to strengthen the theoretical plausibility of the chosen recursive decomposition.

Functions help build the conceptual model. A consequence of this take on functions is that they are never 'established' with certainty but instead stay highly hypothetical in character. This derives from the hypothetical character of structural models in the first place. Structural models provide a mechanistic explanation of a phenomenon *to the best of our knowledge.* But this mechanism is not established for ever, nor are the functions of the mechanism and of the sub-mechanisms. As Franck also stresses, the same functions can be implemented by different causes, and the same causes can have different functions.

We agree with Franck that causes should be incorporated into a putative mechanism only if we can point out their possible function, or rather role-function, in this mechanism. We should therefore avoid integrating into the putative mechanism variables associated with the outcome but for which background knowledge cannot specify their specific functions in the mechanism. We also agree with the view that a same function can be implemented by different means. Functions or roles relate to the conceptual level. We should distinguish between a conceptual model and its operational equivalent. Functions are not empirical variables, though they are derived from observation and implemented by empirical factors. We would like to point out however that the operational or empirical model, though based on observables, is also a theoretical construct: the abstract mechanism it reflects helps the scientist to interpret social data. Actually, all models are abstract representations of reality. As Gudmund Hernes (1998, p. 78) writes:

> Reality presents itself to us, but we have to *represent* it in order to *make sense* of it. Mechanisms are the virtual reality of social scientists.

Causes, functions and contexts. Should an explanatory model be context-dependent or not? Franck gives an example from reverse engineering of an artificial heart, which is borrowed from de Callataÿ (2002 p.108):

> If an artificial heart is grafted to a patient, this heart is an engineering model of the natural heart. This heart uses different pumping principles. It does not use the energy molecules produced by the body. (...) But it still performs the heart's essential function.

We agree that the functions performed by the artificial heart are to some extent the same as some of those performed by the natural one, though the actual mechanisms are quite different. However, if the former fails, one will call upon an engineer to fix it and not upon a cardiologist; vice versa, if one has an infarct, contacting a cardiologist might be preferable to asking help from an engineer.

In other words, we consider—diverging from Franck—that much research in social science is interested in specific contexts *per se*, in a particular place and time, and not in a relatively context-free general model. This is because social research is not conducted solely for knowledge but also for action. For example, we might want to understand or predict, and possibly act upon, the present economic situation of Greece, mortality in Russia, or the political evolution in Cuba. To give another example, one may wish to curb heavy drinking in the Baltic States due to its deleterious activity in the development of cardiovascular diseases, in addition to other causes such as tabacism and obesity. In this case, we are of course not interested in the functional equivalents of drinking as stress-relievers or socialisers, such as those given above, but on alcohol *per se*, that is on *what, why*, and *how* people drink in the Baltic states. In social science, many factors and their interrelations are highly situation-related; it is doubtful that a comprehensive action-oriented explanation can be given with the help of a relatively context-free functional structure—conditional on the possibility of constructing one—rather than by a contextually-dependent empirical causal model. What one would possibly gain in *generality* would be lost in *specificity*.

A context-dependent causal explanation, as proposed in this paper, does not however mean it is necessarily singular (for a discussion of singular causal links when events are not repeated, see Abell 2011). Pierre Demeulenaere (2011b) has convincingly shown that an empirical social mechanism is often generalizable to a large extent because human actions have regular features, ensuring some stability or invariance at a certain time and place. This is firstly due to the fact that many human behaviours are grounded in institutions, rules and norms. People in France or Belgium usually drive on the right-hand side of the road because of the rules of the traffic law and because most people tend to follow these rules. Rules can vary of course in time or location, leading to other regularities. In Britain or in Japan one drives on the left, and Sweden has switched in 1967 from left-hand driving to right-hand driving, but this does not contradict the causal regularity feature. According to Demeulenaere, there is a second reason why social mechanisms are relatively stable: human action is overwhelmingly predictable and agents engage in actions based on typical motives, anticipating typical actions of others that are expected under typical circumstances. Many actions are shaped by routine, even in the absence of institutions and rules, in anticipation of the typical expected reaction of others.

This does not mean of course that all individuals act in the same way. Actually, in many cases, the variance of behaviours is just as meaningful as their average. Rational behaviours are shaped by the institutional context and cultural norms, interrelations with other individuals, available information, resources, values, preferences, beliefs, motives, emotions (see for instance Boudon's theory of *ordinary rationality*, 1998 and 2011), and these factors can vary among individuals. For example, not all Balts are heavy drinkers; some are even teetotallers! Their drinking behaviour is related among other things to their age, gender, health status, ethnicity, education, and economic status (Gaumé and Wunsch 2010). Nevertheless, social regularities—*i.e.* common features of human action—are observed in many circumstances and back up the stability of the causal mechanism. Note that in our view, attributes such as gender or ethnicity can be part of the causal mechanism, contrary to the counterfactual /manipulation approach (see Russo, Wunsch and Mouchart 2011, for a discussion).

One could therefore distinguish between the *functional architecture* of a social mechanism, as discussed above, which could possibly be generalised to some extent across contexts, and the *causal architecture* of a system, which would benefit from an intra-context relative stability. Depending upon the purpose of the research, requiring generality or specificity, one can focus the view either on the functional architecture or on the causal one.

Explaining through social structures. Finally, the functional approach is but one form—albeit an important one—of explanation. Explanations through social structures (e.g., age distribution or occupational composition) is not to be confused with structural-modelling explanations discussed earlier and can supersede functional ones at the macro-level. If some big cities present particularly high homiced rates, it might simply be that the lower socio-economic groups are more represented in their population than in the population of smaller cities or of the rural area, people of lower socio-economic status being more prone to committing homicide than those of higher socio-economic status. To give another example, all demographers know that population crude death rates in developing countries can be lower than those in developed ones, though age-specific risks of dying are higher, because the age structure of the former is younger than that of the latter, and that risks of dying generally increase with age (actually, they decrease with age during the first years of life). Explaining through social structures is often useful as a first step in explanation when the population of interest is composed of different categories and when the behaviour of actors/agents differ among these categories. A next step would be explaining why these behaviours differ among the sub-populations, and this would probably require a structural causal model relying on mechanisms and functions.

5 Discussion and conclusion

Structural modelling is a widespread practice in causal analysis. It has been developed, defended, and discussed by a number of scholars in the social sciences and in philosophy. One peculiarity of the approach defended here is to provide an overarching view of modelling. Namely, structural models incorporate the whole set of assumptions, of testing procedures, and of background knowledge that is needed at each stage of the model building and model testing process; consequently, structural models are not just defined by a (set of) equations. Differently put, structurality lies in the whole model building process, which is not confined to a statistical translation of a pre-conceived theory. Background knowledge and invariance considerations play a central role and complement each other in the construction of the model. Conversely, the recursive decomposition and its possible interpretation in terms of mechanism is central to the explanatory aspect of a structural model. In earlier works we thoroughly discussed issues concerning the model building process and its explanatory features. In this paper, we focus on the role of the concept of 'function' in such context.

There is however a 'functionalist' tradition in sociology, but this is not based on structural modelling in the sense explained in this paper. Functionalism in sociology is therefore outside the scope of this paper. We instead examine the notion of function in structural modelling starting from the debates in the literature on mechanisms. We isolate two discussions that are of interest for our purposes. The first concerns the concept of function cashed out in terms of 'role-function' and of 'isolated description'; this is borrowed from the literature on mechanisms (in biology and neuroscience, mainly). The second concerns the concept of functional architecture; this is borrowed from Robert Franck's philosophy, that tackles social science more specifically.

Having examined these two alternatives, we offer a account of the concept of function in structural explanations. The overall conclusion is that the concept of role-function well suits structural modelling. It allows us to talk about the role, or function, a mechanism has in order to produce some behaviour or phenomenon we are interested in. It also allows us to talk about the role, or function, that the elements of a mechanism play. Concerning this second characterisation, this eventually means specifying the *reasons* to include some causes rather than others in the mechanism and specifying their role. In this sense, functions are the 'theoretical' underpinnings of the causes.

Understanding the relations between function, mechanism, and explanation is relevant because insisting on the importance of identifying the function of a mechanism and of its components (ought to) force the practicing social scientist to justify each step of the modelling procedure. There is no causal rabbit to extract from a statistical hat. There is instead a wise and critical use of background knowledge that helps the statistical machinery extract the best (possible) information from the available data.

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