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"Generative Mechanisms and Multivariate Statistical Analysis: Modeling Educational Opportunity Inequality with a Multi-Matrix Log-Linear Topological Model: Contributions and Limitations"

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Abstract. Among techniques for the quantitative analysis of categorical data, log-linear models at present occupy a central place in social statistics, their sophistication and complexity having rapidly evolved over the past three decades. The article examines a specific variant of this approach to modeling which consists of *log-linear topological models*. It starts from the debate which followed introduction of the latter at the end of the 1970s to offer a new evaluation of the heuristic and methodological utility of this technique in light of recent discussion more generally concerned with the quantitative variables-based approach. In this regard, the article puts forward two arguments. It first maintains that log-linear topological models, especially in their multi-matrix variant, are extremely useful in integrating sociological theory with empirical quantitative analysis. It then shows that the principal shortcoming of these models is that they only partially allow the accurate modeling of the generative mechanisms underlying all the empirical regularities observed in aggregate data. These models are thus very attractive in that they go beyond the descriptive level of numerous works in quantitative sociology, and yet they are incapable of yielding explanations founded on the notion of generative mechanisms. In order not to remain at the abstract level of epistemological reflection, the article will attempt to show the well-foundedness of this thesis by constructing a multi-matrix log-linear topological model for the analysis of a contingency table which cross-classifies social origin with the educational qualification. The model is then tested against French survey data. To the extent that this model attempts to express ideas drawn from a specific theoretical approach – that of '*rational educational choice*' – the analysis can contribute to both the study and understanding of inequalities in educational opportunity.

Key words: empirical quantitative sociology, log-linear topological modeling, generative mechanisms, rational action, inequalities of educational opportunity

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1. Introduction

Analysis of social stratification phenomena is a field in which the variables-based approach has achieved a very high level of sophistication (Cobalti, 1995; Goldthorpe, 2000; Raftery, 2001; Ballarino and Cobalti, 2003). Among the most complex methods used, the type of log-linear model known as 'topological' has had an unusual history. These models were first introduced at the end of the 1970s (Featherman and Hauser, 1978, chap. 4; Hauser, 1978, 1979) and thereafter, for around 10 years, they provoked wide-ranging technical debate (Hauser, 1981, 1986, 1987; Hope, 1981; MacDonald, 1981, 1983; Pontinen, 1982; Jones, 1985, 1986; Kim, 1987). Unlike other advanced techniques, this variant of log-linear modeling has been used by relatively few studies. With the exception of rare attempts to analyze the relation between origins and educational qualifications (Cobalti, 1992, 1996), the few studies to have undertaken topological modeling have been confined to analysis of intergenerational mobility (Goldthorpe [and Payne], 1980, chap. 4; Grusky and Hauser, 1984; Jones et al., 1990; Wong, 1990; Erikson and Goldthorpe 1992, chap. 4–5; Cobalti and Schizzerotto, 1994, chap. 8; Goldthorpe, 1995) or, even more rarely, of intragenerational mobility (Stier and Grusky, 1990). Moreover, the 'innovation rate' has been slow: the majority of studies apply a narrow range of models, notably Erikson–Goldthorpe's model originally proposed in *The Constant Flux* (1992: 121–131). In this respect, the recent study of intergenerational mobility in eleven European countries directed by Richard Breen (2004) is a significant example: most of the 'national' chapters of this important study use – with some variations – Erikson–Golthorpe's 'core social fluidity model' (see in particular chapters 4, 5, 8, 10–13).

Could the rarity of these models be due to their weakness? Ever since their introduction, many researchers have commented on their 'indeterminate' nature, meaning that numerous different matrix specifications could fit the data equally well (MacDonald, 1981, 1983; Pontinen, 1982; see also Hout, 1983: 46–51; Jones, 1986; Jones et al., 1990). The 'equivalent models' problem thus seems to render this class of log-linear models largely vacuous. But this criticism is only valid if one acknowledges a major failure in the field of study in which these models have been applied: the shaky theoretical bases of studies on stratification phenomena.[1] Given solid theories, the extent of the 'equivalent models' problem would change radically, for the choice between different matrix configurations would now be made on theoretical, not empirical, grounds. From this point of view, the problem would reside not in the method but in its applications.

In light of recent discussion on the so-called 'quantitative empirical sociology' approach,[2] however, this article will attempt to re-evaluate log-linear topological models, and in particular their multi-matrix variant. Addressing the problem from this angle will allow a different perspective to be taken on the method, because an evaluation will be proposed that takes account as much of its attractions as of its principal limitation.

It is at present widely acknowledged that: a) there is a gap between sociological theory and empirical research (Coleman, 1990: chap. 1; Hedstrom and Swedberg, 1996; Boudon, 1997, 2002; Goldthorpe, 1997, 2000, intro. and chap. 12, 2003a; Cuin, 2000); and b) that it is impossible to construct good sociological explanations without drawing upon the sociology of generative mechanisms (Stinchcombre, 1991; Blossfeld, 1996; Bunge, 1997, 1998; Boudon, 1998, 2003; Hechter, 1998; Hedstrom and Swedberg, 1998b; Van den Berg, 1998; Cherkaoui, 2000, 2004; Barbera, 2004; Hedstrom, 2005).[3] This does not argue in favor of 'empirical quantitative sociology', where the decoupling of theory from empirical inquiry is particularly radical (Pawson, 1989; Freedman, 1991a, b; Sorensen, 1998; Bäckman and Edling, 1999; Goldthorpe, 2000, chap. 5: 98; Berger, 2002).[4] Undervaluation of the notion of 'generative mechanism' traps this approach in a narrow conception of causality (Abell, 1984; Abbott, 1992a, b; Cox, 1992; Cox and Wermuth, 1993; Goldthorpe, 2000 chap. 7); indeed, the absence of modeling by generative mechanisms limits the explanatory capacity of the quantitative approach to such an extent that the latter is reduced to being a largely descriptive activity (Bunge, 1997; Elster, 1998, 2003; Hedstrom and Swedberg, 1998b: 17; Sorensen, 1998; Cherkaoui, 2000, 2003; Goldthorpe, 2000, chap. 7: 152, 153; Hedstrom, 2003).

There thus emerges a clear opposition between a methodology centered on mechanisms and an approach founded on variables; whilst the former is explanatory, the latter is nothing but a more or less sophisticated description.[5] Though certain authors recognize the somewhat crude character of this opposition (Pawson, 1989: 160–167; Blossfeld, 1996: 185, n. 36; Grusky and DiCarlo 2001), it cannot be denied that the 'degree of permeability' of multivariate analysis to the modeling of generative mechanisms is a crucial methodological issue. With these problems in mind, it is instructive to return to log-linear topological models. On the one hand, the careful use of these models suggests that the variable approach can produce theoretically oriented and informed empirical analyses. On the other, thorough analysis of this method paradoxically suggests that complete implementation of the notion of generative mechanism is probably not possible in the context of multivariate analysis.

I shall attempt to illustrate the well-foundedness of this thesis by means of a concrete example. I shall construct a *multi-matrix topological model* with which to analyze the relation between social origin and educational qualification and then test this model using French empirical data. This will involve:

(1) determining the 'explanandum' and describing it by means of a concise association measure (the *Generalized Odds Ratio*, GOR);
(2) constructing a set of theoretical hypotheses about '*mechanisms*' or '*processes*' presumed to be at the origin of the two-way association described in (1);
(3) translating these hypotheses into a set of level matrices (construction of a *multi-matrix topological model*);
(4) estimating the parameters of the model and comparing the theoretical data that it produces with the observed data described in (1).

Although in what follows the focus will be more on the methodological implications of the analysis than on its substantial findings, two important features of the study should be noted. First, while numerous empirical studies have described the structure and temporal evolution of the association between social origin and educational attainment in France (Garnier and Raffalovich, 1984; Smith and Garnier 1986; Muller and Karle, 1993; Thélot and Vallet, 2000; Vallet, 2004a), very few attempts have been made to explain that association (Goux and Maurin, 1995: 95–105). It is precisely this explanation that is proposed here, and, moreover, by means of an unusual method. Secondly, the theoretical model at the origin of phase (2) of the analysis is largely based on what is now termed the '*rational educational choice approach*' (see Section 2). The testing of variants of this model has begun in several countries: in Italy (Schizzerotto, 1997; Ballarino and Bernardi, 2000), Great Britain (Breen and Yaish, 2003), Denmark (Davies et al., 2002), Germany (Becker, 2003; Hillmert and Jacob, 2003), and Sweden (Jonsson and Erikson, 2000). I am not aware of any studies of this type for France and shall consequently propose one. And I shall do so, moreover, with the help of a technique different from those used in the works just cited.

1. What needs explaining? The configuration of relative educational opportunities

Consider the data set out in Table I,[6] which gives an initial idea of inequalities of educational opportunity in France at the beginning of the 1990s.[7] On comparing row for row the calculated percentages relative to total numbers for each group ('*outflow' perspective*), one notes that the proportion of individuals attaining higher-level qualifications abruptly diminishes as one descends toward socially underprivileged groups. A similar pattern, but in reverse, is apparent at the middle and lower levels of the educational system.[8]

Although interesting, these crude figures only show the distribution by social group of the total volume of available instruction – the *absolute*

Table I. Highest educational qualification obtained by social group of the family of origin[a]. Men and women aged 25–64. Weighted data, FQP survey 1993. Outflow percentages

	E_1	E_2	E_3	E_4	E_5	E_6	E_7	*Tot.*
O_1	33.6	22.4	10.0	4.7	14.4	10.5	4.3	(1517)
O_2	20.8	18.0	9.4	7.2	21.4	14.4	8.7	(1218)
O_3	7.6	12.1	6.4	8.5	35.2	17.6	12.7	(2842)
O_4	7.5	8.7	5.2	6.4	31.7	20.6	19.8	(1620)
O_5	3.0	5.1	2.3	3.5	28.2	27.8	30.1	(2747)
O_6	2.3	5.4	2.4	6.0	35.8	22.1	26.0	(3220)
O_7	1.3	3.4	1.7	3.9	30.2	24.0	35.4	(2351)
Tot.	(1286)	(1438)	(713)	(884)	(4632)	(3211)	(3351)	(15515)

[a] See note 8 for the definitions of (O) and (E).

dimension of educational inequality, as it were. They furnish only very incomplete information on the relative chances of different groups to obtain different qualifications. But it is this *relative and relational* dimension of inequality that is of principal interest here. Required as a consequence is a 'measure' capable of concisely expressing this 'competitive' aspect of educational inequality, of which the row percentages indicated in Table I are only epiphenomena. It seems particularly helpful in this regard to use a coefficient known as the '*odds ratio*' or, if one prefers, the '*conditional probability ratio*'. If L_i and C_j (with $i = 1, \ldots, n$ and $j = 1, \ldots, m$) respectively denote the generic rows and columns of a n, m dimension table – so that (L_i, C_j) denote the numbers to be found at the coincidence of row i and column j – this coefficient can be constructed for four contiguous cases according to (1)

$$[(L_i, C_j)/(L_i, C_{j+1})]/[(L_{i+1}, C_j)/(L_{i+1}, C_{j+1})] \\ = [(L_i, C_j)*(L_{i+1}, C_{j+1})]/[/(L_{i+1}, C_j)*(L_i, C_{j+1})] \quad (1)$$

This is easily generalizable to the table's four non-contiguous cases. Any value between 0 and 1 indicates a negative association; the value 1 represents the absence of association; any value greater than 1 indicates a positive association (Hout, 1983: 16; Bohrnstedt and Knoke, 1998: 162–166; Powers and Xie, 2000: 95–97; Wong, 2003a).[9]

The way in which the coefficient is constructed has two principal advantages. The first is methodological: the value of a '*conditional probability ratio*' remains unchanged under a homothetic transformation of rows and/or columns, or of the table's size (Bishop et al., 1975: 375, 377; Powers and Xie, 2000: 97–99). The second is substantial: the structure of a '*conditional probability ratio*' enables comparison between two social groups on the same educational alternative and thus expresses the over-representation or under-representation of one relative to the other at a given educational level. This measure thus yields a subtle description of the configuration of relative advantages and disadvantages in instructional access enjoyed by the different social groups. It is here that lies the relational dimension of inequality mentioned above. An example will clarify the point. Consider the children of 'higher professionals' (O_1) in relation to those of 'unskilled and agricultural workers' (O_7) and compare their situations in regard to obtaining an 'upper tertiary educational qualification' (E_1) rather than 'no qualification' (E_7): the '*conditional probability ratio*' calculated according to (1) is 212.78. The children born into the first group (O_1) thus have a chance of gaining a higher tertiary diploma 'E_1' 213 times greater than that of the children of 'unskilled and agricultural workers'. It is easy to demonstrate algebraically that this value corresponds exactly to the ratio between the empirically observed proportion of children of 'O_1' obtaining 'E_1' and that theoretically given in the case of an 'odds ratio' equal to 1. Consequently, this measure of association expresses the over-representation (competitive educational advantage) or under-representation (competitive educational disadvantage) of one social group relative to another in relation to a specific educational alternative. Furthermore, this coefficient has an additional advantage: it is easily generalizable. Take, for example, group 'O_1' and qualification 'E_1'. It is possible to calculate a concise measure which expresses the global educational advantage (or disadvantage) of group O_1 in accessing 'E_1', taking account of all possible educational alternatives as well as all relevant social groups. This can be done by calculating the geometric mean of the 36 *odds ratios* expressing each of these comparisons: this complex function of 'simple odds ratios' is known in the literature as the '*generalized odds ratio*' (Kaufman and Schervish, 1986: 719, 721; 1987: 219).

In the context of mobility studies, this measure has sometimes been used to provide a concise description of relative mobility (Cobalti, 1989b, c; 1995; Cobalti and Schizzerotto, 1994; Cobalti and Ballarino, 2003); much more rarely, it has been used to express the relative aspect of educational inequalities (Cobalti, 1992: 139–142). Which is precisely what I propose to do here. The '*generalized odds ratio*' (henceforth, frequently, 'GOR') seem a good device with which to describe, parsimoniously and in a sociologically meaningful way, the structure of competitive advantages implied by the crude percentages in Table I.

Table II presents the collection of these coefficients.[10] Rapid inspection of the table shows that the chances of obtaining different educational qualifications are strongly influenced by social origin: areas of educational advantage as well as disadvantage are clearly identifiable. The children of 'higher professionals' are on average largely over-represented

Table II. Highest qualification obtained by social group of the family of origin [a]. Men and women, aged 25–64. Weighted data, FQP survey 1993. Generalized odds ratios ('GOR')

	E_1	E_2	E_3	E_4	E_5	E_6	E_7
O_1	8.534	3.079	2.663	0.703	0.365	0.388	0.143
O_2	3.589	1.848	1.990	1.008	0.506	0.487	0.304
O_3	1.014	1.204	1.300	1.400	1.109	0.711	0.571
O_4	1.059	0.817	1.062	1.019	1.025	0.938	1.108
O_5	0.476	0.617	0.527	0.697	1.370	2.210	3.061
O_6	0.317	0.641	0.542	1.373	1.797	1.537	2.392
O_7	0.202	0.451	0.478	1.033	1.937	2.331	4.932

[a] See note 8 for the definitions of (*O*) and (*E*).

among the holders of higher qualifications ('GOR' = 8.534 and 3.079) while the children of 'unskilled and agricultural workers' are on average largely under-represented ('GOR' = 0.202 and 0.451). Children from rural and agricultural backgrounds in general are much more likely than all other social groups to have 'no qualification' ('GOR' = 3.061 et 4.932). The 'urban lower-middle class' is the group whose social chances appear on average very close to a situation of nil association: the values of the majority of the '*generalized odds ratios*' are very close to 1.

2. *Explaining the genesis of the configuration of relative educational opportunities: some 'generative mechanisms'*

Although this analysis by '*generalized odds ratios*' correctly describes the structure of educational chances in French society at the beginning of the 1990s, it by no means explains why it should be so. Put otherwise, what explains the specific form and structure of the origins/qualification association revealed by the 'GOR'? Required for this purpose is a sociologically meaningful theoretical model which postulates mechanisms which very likely produce this statistical association observed at the level of aggregate data. As anticipated in the introduction, we now have a consistent theoretical outline of inequalities of educational chances explicitly built on the notions of 'generative mechanism' and 'rational social action'. Although there are differences among the sociologists adopting this approach, the overlaps predominate over the divergences, so that one may consequently speak of a genuine *rational educational choice approach* (Becker, 2003; Boudon, 1973, 1990, 1998: 193–194; Breen, 2001; Esser, 1999, cit. in Becker, 2003; Gambetta, 1987, 1998; Goldthorpe, 2000, chap. 8, 9; Jonsson and Erikson, 2000; Schizzerotto, 1997)[11] which has inspired the collection of 'mechanisms' proposed in this article. The endnotes specify the source of each of my model's components.

The general conceptual framework of this explanatory theory can be summarized as follows: the systematic educational asymmetries that exist between social groups are the result of the aggregate of the intentional behaviors of *N* actors competing, under constraints, for a limited number of social positions. Three components of this theory must be defined: *a)* the actors (their aims and social beliefs); *b)* the resources available to them to achieve their aims; *c)* the systemic constraints to which they are subject.

Three 'mechanisms' define the contours of a stylized actor (component *a*):

- $\boldsymbol{M_A}$**1**. The principal aim of actors in the educational system is to obtain a qualification in order to achieve a socio-occupational position at least as high as that of their family of origin. This first 'mechanism' thus postulates that the prime concern of actors is to avoid downward intergenerational mobility.[12] Paradoxically, this image of actors also suggests that certain social groups will have little need of advanced education in order to 'reproduce'. This is particularly the case of those who can inherit their parent's capital resources (physical or financial).[13]
- $\boldsymbol{M_A}$**2**. It would seem unrealistic to attribute a totalizing dimension to this first objective of action, since this would tend *a priori* to reduce the range of the 'social chances' available to those born into the most disadvantaged groups. I thus postulate that actors, and especially those born into lower social groups, try to take the greatest advantage of the educational system in order to obtain the educational qualifications useful to them in their effort to achieve a higher socio-professional position than that of their parents.[14]
- $\boldsymbol{M_A}$**3**. The third 'mechanism' is the condition for the first two to exist: I hypothesize that, whatever their social group of origin, all individuals are willing to take risks in order to achieve their educational and social objectives. Actors have the right to fail as well as to persevere. It is nevertheless clear that this 'risk propensity' does not have the same meaning for all individuals. In the case of higher social groups, risk-taking expresses an obligation to 'try', even when one does not have the necessary cognitive and intellectual abilities. For those born into a disadvantaged context, by contrast, this willingness to take risks expresses a desire '*to get out at any price*'.[15]

In terms of the typology of social mechanisms proposed by Hedstrom and Swedberg (1998b: 22), $\boldsymbol{M_A}$**1**, $\boldsymbol{M_A}$**2**, and $\boldsymbol{M_A}$**3** are '*mechanisms of action formation*': they explain how individuals reason in a specific social context. Here, we are at the micro-individual level. A final specification is necessary: these three mechanisms function provided that the actors share a system of beliefs on the differential efficiency of qualifications in the labor market such that one can reasonably suppose that, the further one advances in the educational system, the higher one can hope to climb the social scale. This belief is attributed to the actors in my model.[16]

Two other 'mechanisms' express the resources available to the actors (component *b*):

- $\boldsymbol{M_B 1}$. Education involves costs both direct (study materials, registration fees, transportation, lodging, tutoring, etc.) and indirect (opportunity costs). I assume that these costs increase significantly at higher educational levels. The actors have the material and financial resources with which to meet these costs, which vary according to social origin. This mechanism is grounded on the hypothesis that economic resources diminish as one descends the 'social ladder'.[17]
- $\boldsymbol{M_B 2}$. Success at school requires one to possess the cognitive and cultural resources necessary to satisfy the institution's pedagogical requirements. I assume that these requirements become much more demanding as one ascends the levels of the educational system. The process of primary group socialization, as well as the circumstances of everyday family life, affect the degree to which individuals draw upon their cognitive and cultural resources in the educational system. Hypothesized in this case is that, the higher the social group of origin, the more readily accessible these immaterial and symbolic resources become.[18]

In the vocabulary of Hedstrom and Swedberg's typology of social mechanisms (1998b: 22), $\boldsymbol{M_B 1}$ and $\boldsymbol{M_B 2}$ are examples of '*situational mechanisms*' which clarify how the actions of individuals are constrained and influenced by structural elements. Here, we are at the level of complex relations between macro and micro, structure and action.[19]

Finally, two further mechanisms represent the systemic constraints to which the actors are subject (component *c*):

- $\boldsymbol{M_C 1}$. At specific educational levels, particularly those at the top and bottom of the educational hierarchy, I assume the existence in the educational system of processes which group certain individuals together, increasing their chances of success to the detriment of those of other actors. One might term this mechanism the '*mechanism of segmentary amplification of educational opportunity*'.
- $\boldsymbol{M_C 2}$. At the same educational levels, I hypothesize the existence of processes which act in exactly the opposite direction to those discussed above. These are phenomena that distance certain individuals from the educational system, reducing their chances of success and increasing those of others. This mechanism might be termed the '*mechanism of segmentary reduction of educational opportunity*.'

$\boldsymbol{M_C1}$ and $\boldsymbol{M_C2}$ have a different conceptual status from that of $\boldsymbol{M_A1}$, $\boldsymbol{M_A2}$, $\boldsymbol{M_A3}$, $\boldsymbol{M_B1}$ and $\boldsymbol{M_B2}$, for two main reasons: first, it is not obvious how their appropriate analytical level can be determined; second, their theoretical significance is less clearly defined. It seems that these two mechanisms consist of processes that enhance the 'systemic level', in that they concern aspects of social organization imposed on actors without these being able to modify their intensity or direction. Five specific processes can be cited to clarify the nature of $\boldsymbol{M_C1}$ and $\boldsymbol{M_C2}$: (1) cultural proximity or distance between particular social groups or particular parts of the educational institution; (2) the educational segregation resulting from institutionally-defined procedures of distributing students; (3) imitation connected with membership of peer groups; (4) differential selection related to an educational system's varying degrees of historical openness; (5) cognitive stimulation deriving from the historically variable degree of social heterogeneity in educational classes.[20] Viewed from the perspective of inequalities in educational chances, all these processes share an essential feature: they produce opposite effects depending on the social group concerned. $\boldsymbol{M_C1}$ and $\boldsymbol{M_C2}$ belong to a class of mechanisms that Elster calls "Type-B mechanisms": processes acting simultaneously but with opposite effects (1998: 50, 51, 53, 60, 71; 2003). In contrast to the examples given by Elster, however, here I shall be in a position to determine the 'net effect' of these mechanisms – strictly as regards the phenomenon under discussion, of course.

My theoretical model of the genesis of the structure of educational chances thus postulates three groups of mechanisms. The first three – $\boldsymbol{M_A1}$, $\boldsymbol{M_A2}$ and $\boldsymbol{M_A3}$ – operate strictly at the individual level; two others – $\boldsymbol{M_B1}$ and $\boldsymbol{M_B2}$ – concern the relationship between structure and action; the last two – $\boldsymbol{M_C1}$ and $\boldsymbol{M_C2}$ – belong to what one might call, *faute de mieux*, the 'systemic level'.

3. Mathematical modeling: a multi-matrix log-linear topological model

Having formulated the theoretical model, I now need an appropriate procedure with which to test it empirically: that is, I must construct a mathematical 'tool' and find an algorithm which relates my explanatory hypotheses to the data set out in Tables I and II.

Log-linear topological models, I believe, are particularly well suited to this purpose. These models regroup the cases of a contingency table into a limited number of 'classes' which differ among themselves by intensity of association. These groupings are often called 'levels' – hence the terms '*level models*' (Hauser, 1987) and '*level-parameter models*' (Pontinen, 1982). The aim of this operation is to 'dissect' the original association between two variables in a manner that reveals their deep structure. The model thus obtained is both parsimonious and interpretable because it is characterized by a number k of interaction parameters (one per level) less than that of the saturated model (one parameter per case). A simple topological model can thus be expressed in multiplicative or additive form in accordance with (2) and (3) respectively (Featherman and Hauser, 1978: 147–149; Hauser, 1978: 929–931, 1979: 415–417; Gilbert, 1993: 86–91; Powers and Xie, 2000: 111–114; Wong, 2003a):

$$F_{ij} = u^* u_i^* u_j^* u_{ijk} \tag{2}$$

$$\text{Log}(F_{ij}) = \log(u) + \log(u_i) + \log(u_j) + \log(u_{ijk}) \tag{3}$$

where F_{ij} is the frequency obtained with the model for the generic case i, j; u is the parameter expressing the table's sum total; u_i is the parameter expressing the effect of the marginal distribution of the row variable; u_j is the parameter expressing the effect of the marginal distribution of the column variable; and U_{ijk} is the interaction parameter expressing the level of association K to which the case i, j has been attributed.

The greatest difficulty with this type of modelling is the construction of level matrices: on the basis of what criteria are cases to be attributed to the different levels of association? I anticipated this problem in the introduction: if one prefers a theoretically guided strategy to an inductive and exploratory one, this operation is paradoxically the principal attraction of topological models. In this case, the researcher is obliged to develop precise theoretical hypotheses in order to justify the attribution of a case – or, rather, a group of cases – to one or other level of association. In other words, one must have *a priori* 'theoretical mechanisms' in order to postulate that the statistical association between the row variable (social origin, in our case) and the column variable (educational qualification) is more or less strong in some particular region of the table. This 'top–down strategy' becomes all the more constraining and productive when one considers topological models more sophisticated than one consisting of (2) and (3). Instead of constructing a single level matrix, it is in fact possible to construct as many level matrices as there are theoretical hypotheses to test (Gilbert, 1993: 92–95): these are known as "*multi-matrix topological models*" (Erikson and Goldthorpe, 1992: 123) or "*overlapping topological models*" (Wong, 2003a). This type of model is expressed formally in multiplicative terms by (4):

$$F_{ij} = u^* u_i^* u_j^* \prod^{n} (u_{ijk})_n \tag{4}$$

where $(u_{ijk})_n$ denotes the interaction parameter expressing the level of association K to which the case i, j has been attributed at one of the n level matrices. The statistical association in each of the table's cases is thus expressed by a number n of effects which capture the likely factors responsible for the situation of over-representation or under-representation appropriate to the case in question (in our case, that of each origin/qualification pair).

This sophisticated type of topological model has been very rarely applied in studies on social stratification (Stier and Grusky, 1990; Erikson and Goldthorpe, 1992; Cobalti, 1996; Pisati, 1997; see also Jonsson, 2004; Layte and Whelan, 2004; Pisati and Schizzerotto, 2004, for some 'hybrid' applications which combine these models with association model components). It is nevertheless significant that those few authors who have used this method to analyze social mobility have justified their choice by emphasizing that a single level matrix tends to synthetically subsume – and, I would add, hide and conflate – several mechanisms kept distinct by a plurality of matrices. This model thus separates mechanisms in a much more precise and explicit manner (Stier and Grusky, 1990: 751; Erickson and Goldthorpe, 1992: 122–123). It is for these reasons of heuristic utility that I have chosen to construct a *multi-matrix log-linear topological model* with which to implement my theoretical model of the genesis of inequalities in educational opportunity.

In what follows I shall consider the 'mechanisms' postulated in Section 2 in turn and translate them into a structured collection of level matrices. These matrixes will be binary and constructed according to the following principle: if a mechanism $\boldsymbol{M}$ is assumed to produce the situation of over- or under-representation appropriate to the case i, j, it will be attributed value 1; otherwise it will be attributed value 0.

- $\boldsymbol{M_A 1}$ (Table III). In the framework of my model, the offspring of '*high-level professionals*' (O_1) are attracted by the highest-level social positions: they therefore attempt to attain the highest-status and most advanced educational levels (E_1, E_2 and E_3). Although individuals from '*upper-middle professions*' (O_2) and '*lower-middle professions*' (O_3) must attain lower social positions, they can content themselves with progressively lower-level educational qualifications: we will assume that E_2, E_3 and E_4 maximize the chances of O_2 while E_3, E_4 and E_5 represent the qualifications adequate for O_3. Under the same logic, even lower educational levels suffice for the offspring of O_6 and O_7. However, because the former have an interest in attaining the upper and specialized stratum of the labour force, they must climb a little higher in the educational hierarchy than must the latter (E_5, E_6 and E_7 vs. E_6 and E_7). Albeit to differing extents, all these groups need to use the qualification system to maintain their social positions. The functioning of $\boldsymbol{M_A 1}$, by contrast, suggests that this is not the case for the offspring of O_4 and O_5 who want to remain in their group of origin. Because these latter can rely on the hereditary transmission of physical (or, to a lesser

Table III. Level Matrix for (M_A1)

	E_1	E_2	E_3	E_4	E_5	E_6	E_7
O_1	1	1	1	0	0	0	0
O_2	0	1	1	1	0	0	0
O_3	0	0	1	1	1	0	0
O_4	0	0	0	0	0	0	0
O_5	0	0	0	0	0	0	0
O_6	0	0	0	0	1	1	1
O_7	0	0	0	0	0	1	1

extent, financial) capital, education is less indispensable to them. It is for this reason that I do not consider $\boldsymbol{M_A 1}$ – set at zero in the corresponding cases – to operate for these two social groups.

The theoretical nature of $\boldsymbol{M_A 1}$ makes it a factor of over-representation. If my matrix specification is correct, the log-linear parameter expressing the effects of this mechanism – call it $(\boldsymbol{u_{ijk}})^{M_a\mathbf{1}}$ – should thus have a positive value.

– $\boldsymbol{M_A 2}$ (Table IV). Given the image of the social structure discussed above, one cannot suppose that $\boldsymbol{M_A 2}$ operates for the children of 'O_1': there are no socio-professional positions higher than those from which they originate. By contrast, it undoubtedly operates in the case of individuals from 'O_2' and 'O_3', who desire to rise socially. For this purpose they must obtain qualifications more advanced than those required for simple 'reproduction'. This is the case of $E_1$for the former, and of E_1 and $E_2$for the latter. It is equally realistic to assume that certain individuals in groups 'O_4' and 'O_5' wish to move out of self-employment. I shall hypothesize that the vocational and technical tracks of secondary education, E_4 (and higher, E_2, for the children of O_4), can be usefully exploited for this purpose. In the context of my model, $\boldsymbol{M_A 2}$ denotes above all the desire of individuals from disadvantaged backgrounds to 'climb socially', and who consequently seek to take advantage of the educational system even at the most advanced levels. It is for this reason that 1 is assigned to the cases (O_6, E_1), (O_6, E_2), (O_6, E_3), (O_6, E_4) as well as to (O_7, E_2), (O_7, E_3), (O_7, E_4), (O_6, E_5).

The theoretical significance of $\boldsymbol{M_A 2}$ makes it – like $\boldsymbol{M_A 1}$ – a factor of over-representation. If my matrix specification is correct, the log-linear parameter expressing these effects – call it $(\boldsymbol{u_{ijk}})^{\boldsymbol{Ma.2}}$ – should have a positive value.

– $\boldsymbol{M_A 3}$ (Table V). This mechanism is assumed to operate at the highest levels of the educational system for the children of 'O_1', because these

Table IV. Level Matrix for $(\boldsymbol{M}_A2)$

	E_1	E_2	E_3	E_4	E_5	E_6	E_7
O_1	0	0	0	0	0	0	0
O_2	1	0	0	0	0	0	0
O_3	1	1	0	0	0	0	0
O_4	0	1	0	1	0	0	0
O_5	0	0	0	1	0	0	0
O_6	1	1	1	1	0	0	0
O_7	0	1	1	1	1	0	0

Table V. Level Matrix for $(\boldsymbol{M}_A3)$

	E_1	E_2	E_3	E_4	E_5	E_6	E_7
O_1	1	1	1	0	0	0	0
O_2	0	1	1	0	0	0	1
O_3	0	1	0	1	0	1	0
O_4	0	0	0	0	0	0	0
O_5	0	0	0	0	0	0	0
O_6	0	1	1	1	1	1	0
O_7	0	0	0	1	1	1	1

qualifications are indispensable to them if they are to maintain their social positions.

The offspring of 'O_2' are in an analogous position, with an important exception: I assume that they are less protected than the former against total educational failure, E_7. The offspring of those with a '*lower intermediate profession*' (O_3) take risks at two levels in the educational system: first, at the lower level of tertiary education, E_2 (because this may enable them to improve their social positions); second, in secondary level vocational tracks and at the end of primary school (because these qualifications appear indispensable to them if they are not to lose their original social positions). $\boldsymbol{M_A3}$ is assumed not to operate in the case of those who inherit from O_4 and O_5. In contrast to all other social groups, the children of small self-employed workers who seek to improve their social standing through education are relatively well-protected against possible educational failure in that they can inherit the physical capital of their parents. As a consequence of $\boldsymbol{M_A2}$, one must hypothesize that $\boldsymbol{M_A3}$ operates for the most disadvantaged groups. The desire to escape privation among the children of '*skilled workers*' and (to a lesser extent) of '*unskilled and agricultural workers*' induces them to accept the risk of failure and the possibility

Table VI. Level Matrix for (M_B 1)

	E_1	E_2	E_3	E_4	E_5	E_6	E_7
O_1	0	0	0	0	0	0	0
O_2	1	1	0	0	0	0	0
O_3	1	1	0	0	0	0	0
O_4	1	0	1	0	0	0	0
O_5	1	0	1	0	0	0	0
O_6	1	1	1	1	0	0	0
O_7	1	1	1	1	0	0	0

of deferred educational success – that is, of attempting to obtain higher-level qualifications and 'persisting' at lower ones. Assigning 1 to (O_6, E_2), (O_6, E_3), (O_6, E_4), (O_6, E_5), (O_6, E_6) as well as (O_7, E_4), (O_7, E_5), (O_7, E_6), (O_6, E_7) expresses this idea.[21]

The theoretical significance of $\boldsymbol{M_A 3}$ makes it a factor of over-representation. If our matrix specification is correct, the log-linear parameter expressing this mechanism's effect – call it $(\boldsymbol{u_{ijk}})^{\boldsymbol{Ma.3}}$ – should have a positive value.

- $\boldsymbol{M_B 1}$ (Table VI). I postulate that $O_1$is able to pay all the costs of their children's formal education: all these cases are therefore assigned value 0. A lesser capacity to pay, restricted to higher-level education, is assumed for O_2 and O_3. There are no theoretical reasons for thinking that these two groups differ in this respect. The 'indirect' dimension of the cost of education justifies the level attributed toO_4 and O_5: I thus assume that $\boldsymbol{M_B 1}$ operates at levels of the educational system where the link with the labor market is less immediate or definite (especially the general tracks of secondary education, E_3, and the long tracks of higher education, E_1). From the economic point of view implied by $\boldsymbol{M_B 1}$, O_6 and O_7 can be treated in a similar manner: I assume that the difficulties of meeting the costs of education begin with the full secondary level.

The theoretical nature of $\boldsymbol{M_B 1}$ makes it a factor of under-representation. If my matrix specification is correct, the log-linear parameter expressing this mechanism's effects – call it $(\boldsymbol{u_{ijk}})^{\boldsymbol{M_b 1}}$ – should have a negative value.

- $\boldsymbol{M_B 2}$ (Table VII). I assume that the children of O_1 and O_2 have the cognitive and symbolic resources necessary to cope with the pedagogical requirements of school: the action of $\boldsymbol{M_b 2}$ is not postulated for individuals in these groups.

By contrast, at the most advanced level of higher education, E_1, I assume that the offspring of O_3 have cognitive and cultural difficulties.

Table VII. Level Matrix for (M_B **2**)

	E_1	E_2	E_3	E_4	E_5	E_6	E_7
O_1	*0*	*0*	*0*	*0*	*0*	*0*	*0*
O_2	*0*	*0*	*0*	*0*	*0*	*0*	*0*
O_3	*1*	*0*	*0*	*0*	*0*	*0*	*0*
O_4	*1*	*1*	*0*	*0*	*0*	*0*	*0*
O_5	*1*	*1*	*1*	*1*	*0*	*0*	*0*
O_6	*1*	*1*	*1*	*0*	*0*	*0*	*0*
O_7	*1*	*1*	*1*	*1*	*0*	*0*	*0*

Among the children of the 'urban petite bourgeoisie', these symbolic barriers also extend to the lower levels of university education, E_2. The same attribution of level to O_5 and O_7 expresses the idea that the children of the agricultural petty bourgeoisie just as much as those from the most marginalized strata of the working class, must overcome cultural obstacles that begin with full secondary level of education. By contrast, one may assume that the children of skilled workers are in a slightly better situation in the technical and vocational tracks of secondary instruction: it is for this reason that (O_6, E_4) are set at 0.

The theoretical significance of $\boldsymbol{M_B 2}$ makes it a factor of under-representation. If my matrix specification is correct, the log-linear parameter expressing the effects of this mechanism – call it $(\boldsymbol{u}_{ijk})^{\boldsymbol{M_b 2}}$ – should have a negative value.

– $\boldsymbol{M_C 1}$ (Table VIII). The nature of this mechanism suggests that it can only operate in specific and limited zones of the 'origin/qualification' table. One may begin by assuming that processes of 'opportunity amplification' for the children of O_1 exist quite generally in secondary and tertiary education, but they only function at the higher levels for descendants of '*upper middle professions*'. I next postulate that $\boldsymbol{M_C 1}$ operates for the children of O_5, O_6 and O_7 in order to represent their concentration in the positions of most severe educational privation. Finally, I postulate a particular proximity – a sort of 'educational specialization' – between children from working-class backgrounds and the vocational track of secondary school: for which reason (O_6, E_4) and (O_7, E_4) are set at 1.

The theoretical significance of $\boldsymbol{M_C 1}$ makes it a factor of over-representation. If my matrix specification is correct, the log-linear parameter expressing the effects of this mechanism – call it $(\boldsymbol{u}_{ijk})^{\boldsymbol{M_c 1}}$ – should have a positive value.

– $\boldsymbol{M_C 2}$ (Table XI). The action of this mechanism only really affects the social groups situated at the top and bottom of the social scale

Table VIII. Level Matrix for $(\boldsymbol{M_C 1})$

	E_1	E_2	E_3	E_4	E_5	E_6	E_7
O_1	1	1	1	1	0	0	0
O_2	1	0	0	0	0	0	0
O_3	0	0	0	0	0	0	0
O_4	0	0	0	0	0	0	0
O_5	0	0	0	0	0	1	1
O_6	0	0	0	1	0	0	1
O_7	0	0	0	1	0	0	1

Table IX. Level Matrix for $(\boldsymbol{M_C 2})$

	E_1	E_2	E_3	E_4	E_5	E_6	E_7
O_1	0	0	0	0	0	0	1
O_2	0	0	0	0	0	0	1
O_3	0	0	0	0	0	0	0
O_4	0	0	0	0	0	0	0
O_5	1	0	0	0	0	0	0
O_6	1	0	0	0	0	0	0
O_7	1	0	0	0	0	0	0

corresponding to extreme educational outcomes. From this point of view, giving (O_1, E_7), (O_2, E_7), (O_5, E_1), (O_6, E_1), (O_7, E_1) value 1 expresses the idea of a particular distance between these social groups and these specific educational situations.

The theoretical significance of makes $\boldsymbol{M_C 2}$ it a factor of under-representation. If my formulation is correct, the log-linear parameter expressing the effects of this mechanism – call it $(\boldsymbol{u_{ijk}})^{\boldsymbol{Mc.2}}$ – should have a negative value.

All of the 'theoretical mechanisms' have now been translated into the language of level matrices. My *log-linear topological model* for Table I can now be expressed in multiplicative form in accordance with (5):

$$F_{ij} = u^* u_i^* u_j^* (u_{ijk})^{Ma.1*} (u_{ijk})^{Ma.2*} (u_{ijk})^{Ma.3*} (u_{ijk})^{Mb.1*} (u_{ijk})^{Mb.2*} (u_{ijk})^{Mc.1*} (u_{ijk})^{Mc.2} \qquad (5)$$

This formulation states that the totals observed in each of the table's cases can be approximated by the product of three terms representing the structural aspects of the sample and by seven terms expressing the postulated 'theoretical mechanisms'. Note that not all cases will have the same parameter structure, in the sense that parameters corresponding to mechanisms whose action has not been postulated will be absent: in mathematical

Table X. Results of fitting the 'Multi-Matrix Log-Linear Topological Model' [5] to the 1993 French origins/qualifications table

A) Goodness-of-fit measures							
	Dl	L^2		*Bic*	*ID*	rL^2	L^2/dl
Independence	36	3558.92 *(0.000)*		3211.54	0.170	–	98.86
Topological	29	25.63 *(0.645)*		−254.21	0.015	99.28	0.88
B) Parameters							
	$(u_{ij})^{M_a1}$	$(u_{ij})^{M_a2}$	$(u_{ij})^{M_a3}$	$(u_{ij})^{M_b1}$	$(u_{ij})^{M_b2}$	$(u_{ij})^{M_c1}$	$(u_{ij})^{M_c2}$
Multiplicative	1.785	1.427	1.409	0.868	0.549	1.544	0.420
Log-additive	0.580	0.355	0.343	−0.142	−0.599	0.434	−0.869
S.E.	(0.039)	(0.047)	(0.028)	(0.045)	(0.049)	(0.032)	(0.062)

terms, they will have a value of '1' (or '0', if the model is expressed in additive form). In the context of such a *multi-matrix topological model*, the parameter of final association of each case will thus be derived from the product of the specific effects applying to it, as indicated by the term $\prod^n (u_{ijk})_n$ in (4).

4. Estimation, evaluation, and statistical analysis of the model

Having translated the theoretical model into a *multi-matrix log-linear topological model*, I must now determine whether it does in fact correctly reproduce the empirical data. Table X reports the principal results of the estimation on the basis of the French data set out in Table I.[22]

Part (A) of the table reports five goodness-of-fit statistics. Each of them can be compared to the same statistics calculated for the model of statistical independence between origin and qualification. As common in the literature, this model is considered to be the baseline model.

Given a loss of only seven degrees of freedom relative to the independence model, the results are undeniably appealing:

(1) L^2 expresses the global proximity of theoretical frequencies $[F_{ij}]$ to observed frequencies $[f_{ij}]$: its value is astonishingly low for a model applied to a sample of 15,515 individuals.[23] The statistically non-significant value of differences between the data produced by the model and the observation data should be noted: in log-linear analysis, a 'p-value' of 0.645 suggests that such differences can be considered as resulting from stochastic fluctuations, rather than from a poor specification in the theoretical model.

(2) The strongly negative value of *Bic* indicates that my model achieves a highly satisfactory balance between parsimony and reproduction of the observation data.[24]

Table XI. Standardized Residuals with the multi-matrix topological model [5]

	E_1	E_2	E_3	E_4	E_5	E_6	E_7
O_1	0.629	0.194	−0.848	1.329	−1.377	0.420	−0.127
O_2	−1.091	0.623	−0.195	1.004	−0.358	0.402	0.267
O_3	0.850	−0.481	0.457	0.428	−0.116	−0.278	−0.300
O_4	−0.574	−0.098	1.008	−1.389	0.476	0.665	−0.474
O_5	−0.112	−1.182	−0.367	−0.554	−0.190	−0.241	1.291
O_6	0.561	1.360	0.067	−0.860	0.046	−0.891	0.438
O_7	−0.884	−0.522	0.071	0.779	0.914	0.628	−1.227
		Mean = 0.0035; standard error = 0.7304.					

(3) The value of the index of dissimilarity is extremely low.[25] Of 15,515 individuals, only 1.5% of them – or around 232 individuals – were misclassified by the model's predictions.

(4) The value of rL^2 is very high: my topological specification eliminates nearly 99.30% of the distance between the data produced by the independence model and the empirical data.[26]

(5) The ratio between L^2 and the number of degrees of freedom is very close to 1, which suggests that the model is correctly specified.[27]

To be stressed is the coherence of these goodness-of-fit statistics. Each of them expresses a specific way to evaluate the proximity of the theoretical data to the empirical data, and yet all of them assume values which support strong acceptance of the topological specification. It is precisely this stability and convergence of the evaluation indices which suggest that my topological translation of the theoretical model of the genesis of educational inequalities is able to explain the French data presented in Table I.[28]

Moreover, two further proofs of its goodness are available.

First, the structure of the standardized residuals (Table XI) shows that my topological model correctly reproduces the observation data, and in strongly homogenous manner: that is, it does so equally well whichever 'origin/qualification' pair one chooses to consider. All of the residuals are less than 2.[29]

Second, it is possible to calculate the '*generalized odds ratios*' ('GOR') using the multi-matrix topological model and compare them with the same coefficients calculated on the basis of the empirical data (discussed in the first section, Table II). Rapid inspection of Table XII shows that the model produces coefficients whose values are astonishingly close to those of the empirical 'GOR'. The topological specification thus produces a structure of educational opportunity very similar to the one observed empirically. There is obviously a strong temptation to consider the theoretical 'mechanisms' at

Table XII. Generalized Odds Ratios under the multi-matrix topological model [5] – in bold type – and observed Generalized Odds Ratios (FQP 1993)

	E_1	E_2	E_3	E_4	E_5	E_6	E_7
O_1	***8.084***	***3.047***	***2.973***	***0.588***	***0.413***	***0.381***	***0.148***
	8.534	3.079	2.663	0.703	0.365	0.388	0.143
O_2	***3.912***	***1.767***	***2.092***	***0.910***	***0.525***	***0.484***	***0.299***
	3.589	1.848	1.990	1.008	0.506	0.487	0.304
O_3	***0.923***	***1.255***	***1.265***	***1.398***	***1.114***	***0.743***	***0.590***
	1.014	1.204	1.300	1.400	1.109	0.711	0.571
O_4	***1.096***	***0.817***	***0.911***	***1.243***	***0.973***	***0.897***	***1.135***
	1.059	0.817	1.062	1.019	1.025	0.938	1.108
O_5	***0.455***	***0.678***	***0.545***	***0.744***	***1.317***	***2.191***	***2.772***
	0.476	0.617	0.527	0.697	1.370	2.210	3.061
O_6	***0.288***	***0.564***	***0.551***	***1.559***	***1.806***	***1.663***	***2.384***
	0.317	0.641	0.542	1.373	1.797	1.537	2.392
O_7	***0.239***	***0.476***	***0.464***	***0.927***	***1.788***	***2.236***	***5.110***
	0.202	0.451	0.478	1.033	1.937	2.331	4.932

the basis of this log-linear operationalization as the processes truly responsible for inequalities of educational opportunity (in the spatial and temporal context covered by our data, of course).

From this point of view, it is particularly instructive to move from evaluation of the global adjustment of the *model (5)* to analysis of the structure of its parameters: *part (B)* of Table X. First to be considered is the following essential feature: the values of the parameter standard errors show that these latter are all statistically significant ($p < .001$, except for $(\boldsymbol{u}_{ij})^{M_b\mathbf{1}} : p < .002$). A second important feature should also be noted: all the signs of these parameters correspond to expectations (see *Section 3*). Thus

(1) $(\boldsymbol{u}_{ijk})^{M_a\mathbf{1}}$, $(\boldsymbol{u}_{ijk})^{M_a\mathbf{2}}$ and $(\boldsymbol{u}_{ijk})^{M_a\mathbf{3}}$ are positive, which makes them factors of over-representation for the relevant cases: which is indeed the direction in which the mechanisms $\boldsymbol{M_A}\mathbf{1}$, $\boldsymbol{M_A}\mathbf{2}$ and $\boldsymbol{M_A}\mathbf{3}$ operate. All of them express processes which induce individuals to use education as a means to achieve individual and social fulfillment.

(2) $(\boldsymbol{u}_{ijk})^{M_b\mathbf{1}}$ et $(\boldsymbol{u}_{ijk})^{M_b\mathbf{2}}$ are negative, which makes them factors of under-representation for the relevant cases: this is the 'diminishing effect' of educational chances implied by the mechanisms $\boldsymbol{M_B}\mathbf{1}$ and $\boldsymbol{M_B}\mathbf{2}$, both of which represent a lack of resources on the part of actors with which to exploit of the educational system.

Table XIII. Results of fitting the 'Multi-Matrix Log-Linear Topological Model' [5] to the 1993 French origins/qualifications table with all its effects and removing one effect at a time

	Dl	L^2	*Bic*	*ID*	rL^2	L^2/dl
[5] - $u_{ij}^{M_a1}$	30	248.57 (0.000)	−40.92	0.044	93.01	8.29
[5] - $u_{ij}^{M_c2}$	30	248.29 (0.000)	−41.20	0.040	93.02	8.23
[5] - $u_{ij}^{M_c1}$	30	207.88 (0.000)	−81.61	0.046	94.16	6.93
[5] - $u_{ij}^{M_a3}$	30	183.03 (0.000)	−106.45	0.041	94.86	6.10
[5] - $u_{ij}^{M_b2}$	30	175.53 (0.000)	−113.95	0.040	95.07	5.85
[5] - $u_{ij}^{M_a2}$	30	83.30 (0.000)	−206.18	0.026	97.66	2.78
[5] - $u_{ij}^{M_b1}$	30	35.38 (0.229)	−254.10	0.018	99.01	1.20
[5]	29	25.63 (0.645)	−254.21	0.015	99.28	0.88

(3) $(\boldsymbol{u_{ijk}})^{\boldsymbol{M_c1}}$ is positive, which makes it a factor of over-representation for the relevant cases: this is exactly the meaning of mechanism $\boldsymbol{M_C1}$, which expresses the action of systemic processes increasing the educational opportunities of certain groups.

(4) $(\boldsymbol{u_{ijk}})^{\boldsymbol{M_c2}}$ is negative, which makes it a factor of under-representation for the relevant cases: this is perfectly in keeping with the theoretical interpretation of mechanism $\boldsymbol{M_C2}$, which postulates the existence of processes that reduce the educational chances of certain social groups.

The structure of the parameters of *model (5)* thus further evidences that it is a correct and coherent representation of the processes generating the empirically observed configuration of educational opportunity inequalities in French society at the beginning of the 1990s.[30]

A final analytic operation seems of particular theoretical interest: evaluating the relative importance of these 'mechanisms'. I shall proceed as follows. Starting from the *multi-matrix topological model (5)*, including all its effects; I shall subtract one parameter at a time and then assess the model as modified. Analysis of variations in the value of the goodness-of-fit measures should thus yield a relatively precise idea of the contribution made by each 'mechanism' to the global fit of the model. Table XIII reports the results of this operation after the models have been ordered according to the values of L^2.

Apart from the relatively stable value of the index of dissimilarity in five out of seven models, all the statistics go in the same direction. With regard to the complete version of my theoretical formulation, the exclusion of the effects corresponding to $\boldsymbol{M_A1}$ and $\boldsymbol{M_C2}$ causes the largest decrease in the model's fit quality.

These two mechanisms respectively correspond to an individual micro component and a systemic one: which may well signify that, in order to represent the reality of inequalities educational opportunity correctly, once must strike the correct balance between voluntarism of action and institutional constraints. This seems to be confirmed by two other mechanisms, $\boldsymbol{M_C 1}$ and $\boldsymbol{M_A 3}$, where the suppression of the corresponding parameters strongly distances (although to a lesser extent in the first case) the theoretical data from the observation data. Here, too, the former mechanism expresses systemic effects while the latter expresses the risk propensity of social actors. The elimination of parameter $(\boldsymbol{u_{ijk}})^{\boldsymbol{M_b 2}}$ corresponding to mechanism $\boldsymbol{M_B 2}$ (expressing constraints of a symbolic nature) as well as that of parameter $(\boldsymbol{u_{ijk}})^{\boldsymbol{M_a 2}}$ corresponding to mechanism $\boldsymbol{M_A 2}$ (which expresses 'desires' for social advancement) similarly results in a non-negligible deterioration in fit quality – in the former case more so than the latter. Once again we have a mechanism, $\boldsymbol{M_B 2}$, tied to the structural aspects of social action, as well as a mechanism, $\boldsymbol{M_A 2}$, of a more micro-individual character. The behavior of the model after $(\boldsymbol{u_{ijk}})^{\boldsymbol{M_b 1}}$ – corresponding to mechanism $\boldsymbol{M_B 1}$ which expresses the effects of economic resources on educational choice – being uniquely removed has a partly unexpected result: the model adjusts relatively well to the empirical data. However, the '*p*-value' is considerably less than that of the complete model *(5)*: it would be wrong to accept the former in place of the latter as a correct representation of the process by which inequalities of educational opportunity arise. The probability that discrepancies between theoretical data and observation data will be attributed to stochastic variations, when these discrepancies in fact derive from an incorrect model specification, is much greater in the case of a model which does not contain the mechanism expressing the costs of education. Contrary to what one might have expected, it remains no less true that the relative importance of this mechanism is partially 'resized' by a detailed analysis of our model.[31]

2. Discussion

The principal aim of this article has been to reconsider, from a different perspective, log-linear topological models, and especially their multi-matrix variant, the purpose being to evaluate their significance and implications relative to the debate of the 1980s. We can now attempt a general assessment.

The foregoing analysis has shown that the 'equivalent models' problem is far from being a major obstacle to application of this method. Theoretical and interpretative indeterminacy can be greatly reduced if one rejects a strategy of inductive and technical construction founded on 'trial and error' and instead adopts a deductive point of view that considers matrix-specification as a technical device to translate theoretical hypotheses explicitly stated *a priori* into. Constructing a log-linear topological model implies that one has a theory capable of generating and explaining the alternation of zones of weak and strong observable concentration – for example, in the 'qualifications by origin' table. Sociologists are obliged to explain their theoretical hypotheses and, above all, to state how they have moved from these to the level matrices indispensable for statistical estimation of the model. From an algebraic point of view, it will always be possible to put together a series of level matrices leading to heterogeneous models but capable of producing equivalent theoretical frequencies. But one wonders whether such an exercise is of anything other than computational interest. If a level matrix is theoretically constructed, the discussion moves to how the researcher has operationalized his/her theoretical hypotheses. If it is possible to demonstrate that two (or several) alternative matrices express the same relations between the same hypotheses, why should this be a danger to sociological interpretation? Conversely, if it is possible to demonstrate that two (or several) alternative matrices expressing different relations between different theoretical hypotheses result in similar adjustments, why should this disqualify topological models? This would be the classic case in which several theoretical models compete with one another to represent the same phenomenon. Is this a statistical question or rather a problem of rational debate on the model most justifiable from an epistemological and theoretical point of view? Moreover, there is persuasive evidence that the use of complex – that is, multi-matrix – versions of topological models further reduces the 'equivalent model' problem because it obliges the sociologist to construct an articulated set of analytically distinct theoretical hypotheses. Since these hypotheses will be operationalzed by means of a series of separate level matrices, it is all the more possible to control and criticize the model's internal coherence, as well as the manner in which its articulation has been translated into specific groups of level matrices. Some authors have acknowledged the value of a deductive and confirmatory strategy of this kind (Goldthorpe and Payne, 1980: 95; Cobalti, 1992) as well as the attraction of multi-matrix variants (Erickson and Goldthorpe, 1992: 122–123; Cobalti, 1996). The potential of the latter has also been confirmed by hybrid applications which combine topological and association models (Pisati, 1997; Jonsson, 2004; Layte and Whelan, 2004; Pisati and Schizzerotto, 2004). It is thus possible to move away from the exploratory and incremental approach originally proposed by Hauser (Featherman and Hauser, 1978: 140; Hauser, 1979: 435–444).

If one accepts these arguments, one can only conclude that log-linear topological models, and especially their multi-matrix variant, are of undeniable interest. They introduce theoretical reflection and systematic conceptual elaboration into quantitative data analysis. The methodological implications of such a conclusion are no less significant: this article has shown (at least for one specific case) that it is entirely possible to construct empirical quantitative analyses that go well beyond the purely descriptive level. It is one thing to point out that this is rarely the case among the supporters of the variable approach; it is quite another to deny *a priori* that any such thing is possible. My analysis has suggested that giving a purely descriptive task to variable analysis implies an excessively categorical judgment which tends to equate the logical possibilities ('rich') of this approach with the research practice ('poor') of numerous quantitative sociologists.

However, the real problem with log-linear topological models lies elsewhere. Even if one were to admit their capacity to relate sociological theory to empirical data, one is obliged to recognize that they are unable to implement the generative mechanism approach. The debate of the 1980s entirely neglected this crucial point.

Careful examination of the research approach presented in sections (2), (3), and (4) should suffice to show that the methodological perspective of generative mechanisms has only been partially implemented. Why is this so? There are two reasons. First, although I have constructed my theory in terms of generative mechanisms, the manner in which these latter have been 'restored' to the empirical data does not constitute the 'direct modeling' of their structure and action. In other words, the mechanisms postulated as generating inequalities in educational chances have been treated in largely imaginative and abstract fashion. I have constructed a theoretical representation without being able to manipulate it directly. Translating these mechanisms into a group of level matrices is only a partial solution from the perspective of a study aimed at manipulating and testing a series of generative mechanisms. The relations that the approach is able to establish between these latter and empirical data are rather weak and, above all, indirect. Indeed, the matrices impose theoretically significant constraints on the model: the theoretical data thus undeniably result from a rule of production. This latter, however, does not directly represent a process; rather, it is the possible result thereof. For example, the model was required to place more individuals from the socially superior group at the level of the highest qualifications and attribute theoretical significance to this constraint by way of level attributions in the different matrices. Yet it did not directly represent the stylized actors who attributed different values to different qualifications according to their social group of origin (which is to say, the mechanism, or rather a part of it, rather than its effects). Second, certain components of my theory – in particular, $\boldsymbol{M_a 1}$, $\boldsymbol{M_a 2}$ and $\boldsymbol{M_a 3}$ (see note 19) – imply a conception of formal education as a 'positional good', in the sense that the value of a qualification depends on its distribution in the population. This suggests that the actors in the model are potentially in a situation of interdependence. It is essential to take this feature into account when offering generative mechanism explanations, because it is precisely this notion of interdependence which authorizes one to use the concept of emergence. The structure of educational chances can only be characterized as emergent relative to individual actors if it derives from a network of individuals who determine their actions and choices in relation to those of the others. Although these features are implicitly present in the theoretical plan, the matrix specification of the model is entirely unable to grasp them. Once again, it captures the *effects* of inter-dependence, not its structure or function. We thus have two formidable difficulties. However sophisticated and theoretically well-grounded my multi-matrix log-linear topological model may be, it only yields in another form the data with which we determined its parameters. The extent of this difficulty has been underestimated even by methodologists sensitive to the notion of mechanism, such as Ray Pawson (1989: 171–175), who have placed the uni-matrix topological model constructed by Goldthorpe and Payne (1980) in the category of generative models.[32]

These difficulties have implications that extend beyond, I believe, this specific method. It is quite likely a major obstacle against any attempt to implement explanations centered on mechanisms in the context of 'quantitative empirical sociology'. The variable approach appears, at least at its present state of technical development, unable to describe and implement a theoretical mechanism in dynamic and iterated manner. The parameters of a statistical model, no matter how sophisticated, are at best a representation (a fiction, we might say) of the effects of mechanisms imagined at the theoretical level. The estimation algorithms used to produce these parameters do not have strict relations with these theoretical mechanisms: they do not in the least constitute direct translations of them, because they have not been created to describe, activate, or implement them. Moreover, the statistical techniques used to study stratification phenomena privilege a representation of data where explanatory factors are summarized one after the other, rather than being organized into a structured configuration of factors. The idea of a 'logic' of data production processes is thus broken down into a series of elements each of which separately produces sequential-type effects. However, one could probably move towards solution of these difficulties by using a partly different methodological approach. The attraction of certain simulation techniques is that they dynamically represent the structure and the functioning of a series of mechanisms. In regard to the latter, the computer program that generates the model is explicitly conceived and constructed to implement the mechanisms postulated at the theoretical level. If correctly chosen, a specialized programming language enables one to produce a structured group of algorithms expressing the mechanisms of interest. In this sense, one can legitimately speak of the 'direct modeling of mechanisms': each algorithm is conceived to translate a specific process into a language comprehensible to the computer. The purpose of the algorithm is not to enable statistical estimation of a model's parameters, to which the researcher then assigns such and such a meaning.

On the contrary, it is constructed to represent – and articulate – one or several very specific sociological ideas.

I conclude this article by putting forward a strong methodological hypothesis: if we wish to get closer to real sociological explanations centered on the idea of mechanisms, we must leave the methodological context of the sociology of variables and enter a somewhat different paradigm: that of simulation methods and techniques.[33] Hence, the problem of quantitative empirical sociology's 'degree of permeability' to the generative mechanism approach must be conceived in terms of the articulation and integration of different methods; a solution that refuses to go beyond multivariate analysis will very likely not be viable. I have explored the epistemological presuppositions of this idea elsewhere (Manzo, 2005) and I am at present working on its concrete application to the study of inequalities in educational opportunities.

Notes

1. This is openly acknowledged to an increasing extent (Cherkaoui, 2003b; Goldthorpe, 2003b; Jonsson, 2004). Few attempts have been made to construct a micro oriented theory of relative mobility (Logan, 1996; Pisati, 1997; Goldthorpe, 2000, chap. 11); indeed, doubts have recently been expressed as whether such a theory is possible (Breen and Jonsson, 2003; Breen, 2004, chap. 15: 390–392, 402).
2. There are several terms in the literature for this approach: '*variable-centered methodology*' (Abell, 1984), '*variable-oriented approach*' (Ragin, 1987, chap. 4), '*variable-based approach*' (Abbott, 1992a: 441), '*standard positivist analysis*' (Golthorpe, 2000, chap.5), '*quantitative sociology*' (Backman and Edling, 1999), '*positivist sociology*' (Cherkaoui, 2000, 2000a). I prefer *quantitative empirical sociology* in order to stress that '*variable sociology*' does not exhaust quantitative sociology: there is another form of quantitative sociology which is purely theoretical – that is, *mathematical sociology* – and has its own status and legitimacy (Fararo, 1984: 219; 1997: 91; Collins, 1992: 619–640; Edling, 2002: 202). Without wanting to deny the importance of the following question, space precludes its discussion here: Is it legitimate to speak of '*quantitative sociology*'? The epistemological debate on the ambiguities of the distinction between 'quantitative approach' and 'qualitative approach' no doubt merits closer attention than is possible here (see, for example, Cannavo, 1988; Cardano, 1991; Agodi, 1996).
3. On this point, contemporary sociology is rediscovering its oldest findings: see, in particular, Boudon (1973, 1976, 1979), Fararo (1969, 1989), Harré, Secord (1972), Merton (1967).
4. As Cherkaoui remarked (2003a), this criticism is much older: see Wright Mills (1959).
5. If one adds to this criticism the more general attacks on quantitative empirical sociology set out in such important works as those by Clogg and Haritou (1997) and Esser (1996), one well understands why certain scholars today seek to construct systematic proposals for improvement in variable sociology. See, for example, Andrew Abbott (1990, with Hrycak; 1992a, b; 1995; 2000; 2000, with Tsay), Peter Abell (1984, 1998, 2003), or Hans-Peter Blossfeld (1996, 1998).
6. The data are taken from the 1993 '*Formation-Qualification professionnelle*' (*FQP*) survey conducted by INSEE (the French *National Institute of Statistics and Economic Surveys*):

I use a sample of 15,515 individuals, men and women aged between 25 and 64s. The FQP survey data have been widely analyzed by studies on inequalities in educational opportunity (Goux, 1995; Vallet, 1999, 2004b) and social mobility (Erikson and Goldthorpe, 1992; Goldthorpe, 1995; Vallet, 1999, 2004b): their quality is largely recognized at the international level (Breen, 2004). In order to obtain the most representative data possible, I have adopted a procedure for weighting the 1993 data designed to correct certain biases introduced by the survey's sample design. More specifically, I 'simulate' a simple random sample (Vallet, 2004c). See also note 22.

7. A bi-dimensional contingency table contrasting origin and educational outcome thus constitutes the analytic framework of this study. It is not the only possible approach, however. Since the beginning of the 1980s, the better part of studies on inequalities in educational opportunity have adopted what is known as the 'educational transition' perspective, according to which the educational system is ideally fragmented into a sequence of levels and points of bifurcation which is used to model the probabilities of moving from one level to next as a function of social origin. This perspective was introduced by Boudon (1973). Following the work of Robert Mare (1980, 1981), this strategy was implemented by means of logistic regression models: the most important comparative study of the 1990s is a clear example of this approach (Shavit and Blossfeld, 1993). This perspective has recently been subject to criticism (Breen and Jonsson, 2000). See Vallet (2001a) for a detailed account. The present study thus takes a different approach, what Vallet calls a "*contingency table approach to educational stratification*".
8. The classification of social groups used here is based upon a re-codification of INSEE's two-figure nomenclature of '*professions and socio-professional categories*' (Desrosières and Thévenot, 2002: chap 4 and pp. 105–114). In particular: $\boldsymbol{O_1}$: '*Higher-grade professionals, Liberal Professions, Business Managers*' (PCS 23, 31, 33, 34, 35, 37, 38); $\boldsymbol{O_2}$: '*Higher Intermediate Professions*' (PCS 42, 43, 44, 45, 46); $\boldsymbol{O_3}$: '*Lower Intermediate Professions*' (PCS 52, 53, 54, 55, 47); $\boldsymbol{O_4}$: '*Urban Petite bourgeoisie*' (PCS 21, 22); $\boldsymbol{O_5}$: '*Agricultural petite bourgeoisie*' (PCS 10); $\boldsymbol{O_6}$: '*Skilled Workers*' (PCS 48, 62, 63, 64, 65); $\boldsymbol{O_7}$: '*Unskilled and Agricultural Workers*' (PCS 56, 67, 68, 69). Note that these variables refer to the '*social group of family of origin*' in the sense that it considers, by means of the 'principal of dominance' (Erikson and Goldthorpe, 1992: 238–239, 265–266), the profession of both the mother and the father. See Pisati (2000) and Vallet (2001b) for the complex debate on determination of 'social family class'. In order to determine the proximity between this classification and that typically used at the international level, see, for example, Goldthorpe (1995: 65); Thélot, Vallet (2000: 6) propose a similar re-codification.

   As regards educational qualifications, the present study adopts a seven-position classification of educational levels based on re-codification of INSEE's 14 position classification of educational levels. In particular, $\boldsymbol{E_1}$: '*Upper tertiary education diplomas*' (code 10, 11); $\boldsymbol{E_2}$: '*Lower tertiary education diplomas*' (code 30, 31, 32, 33); $\boldsymbol{E_3}$: '*Upper general secondary education diplomas*' (code 40, 41); $\boldsymbol{E_4}$: '*Upper technical or professional secondary education diplomas*' (code 42, 43); $\boldsymbol{E_5}$: '*Short-term professional studies*' (code 50, 51); $\boldsymbol{E_6}$: '*Primary education diplomas or lower general secondary education diploma*' (code 60, 70); $\boldsymbol{E_7}$: '*No diploma*' (code 71). Similar classifications have been used by Thélot, Vallet (2000: 6) and Vallet (2004b).
9. It is precisely this property which has prompted the decision to abandon other measures of inequality which, by contrast, do not benefit from it. In the case of the study of the temporal dimensions of educational inequalities, there is long-standing debate on the use of simple differences or percentage ratios (Mare, 1980, 1981; Barbut, 1984, 1985; Combessie, 1984, 1985; Florens, 1984; Gremy, 1984; Merllié, 1985; Prévot, 1985; Vallet,

1988; Cobalti, 1989a). The same holds for studies of mobility (Cobalti, 1989b, c; 1995). The work of John Goldthorpe has had a major role in the spread and acceptance of this measure of association for studies of the relative aspect of social inequalities (Goldthorpe, 1980: chap.3; Erikson and Goldthorpe, 1992: 54–59, 86).

10. Kaufman and Schervish (1987: 233, 251) have shown that the 'Generalized Odds Ratios' can be calculated (on condition that three-way, or even higher-order, parameters are not present in the model) on the basis of bi-variate parameters in the multiplicative form (τ_{ij}) of the saturated log-linear model estimated in parameterization of ANOVA-type on the basis of $[\tau_{ij}]^{(ij)/(i-1)(j-1)}$, i and j being respectively the number of rows and columns.
11. I have described this approach elsewhere: for the details, see Manzo 2004a.
12. This individual micro mechanism was already postulated in Boudon (1973; and, more clearly, 1990: 17, 18); it thereafter became the essential aspect of the rational theory of educational choice in the version of Richard Breen and John Goldthorpe (Goldthorpe, 2000, chap.8: 175; chap.9: 186,189,196).
13. In the context of a micro theory based on the relative aspect of social mobility, this hypothesis has been explicitly put forward by Goldthorpe (2000, chap.11: 245) and Pisati (1997).
14. On this point, there is an important difference of emphasis between my model and that available in the literature. Although Goldthorpe (2000, chap. 11: 242) admits the existence of this goal in disadvantaged social groups, he attributes a secondary role to it and, in any case, he only raises the point in the context of his more recent sketch of a theory of the relative aspect of social mobility.
15. Whilst the former meaning of the risk-taking mechanism is widely recognized in the rational educational choice model (see, for example, Goldthorpe, 2000, chap. 8: 175; chap. 9: 195; chap. 11: 249; Jonsson and Erikson, 2000: 364), I take a much clear and more definite stance on latter meaning - the propensity for risk-taking in socially disadvantaged groups. As Grusky and Di Carlo (2001) have stressed, Goldthorpe (2000: 245–247) leans towards a hypothesis of risk aversion among the most disadvantaged. The results of recent research suggest the legitimacy of my position: at least in France, there is empirical evidence for the existence of a strong aspiration for upward social mobility among the most disadvantaged social groups (Beaud, 2003).
16. Goldthorpe (2000, chap. 9: 187–188) has emphasized the importance of this assumption for the model's coherence.
17. The mechanism of the economic costs of instruction is largely taken into account by the authors who have inspired my approach (Goldthorpe, 2000, chap. 8: 173–174; chap. 9; 185–186; Gambetta, 1987, 1998; Jonsson and Erikson, 2000). Raymond Boudon attributes it a central role in generating inequalities of educational opportunity (1973: 75, 115–116, 129–130, 210; 1990: 22, 23, 24, 30).
18. Although the 'rational model of educational choice' undeniably takes account of cultural resources, it is also true that the status of the latter is ambiguous. Their importance is recognized by some authors more than others (see, for example, Jonsson, Erikson [2000] and Gambetta [1987]), but they are often introduced indirectly by means of the effects they exercise on educational success in the early phases of a student's academic career. See, in particular, the distinction between primary and secondary effects (Boudon, 1973: 63, 67, 69–70, 72, 103; Goldthorpe, 2000, chap. 8: 171; chap. 9: 186, 190–191, 192). By contrast, I maintain that a solid model must attribute a central theoretical role to the effects of socialization in terms of the immaterial and symbolic resources that this process transmits to individuals. It is on precisely on this point, moreover, that the rational model of educational choice is most often criticized (Goux and Maurin, 1995; Massot, 2000; Esping–Andersen, 2003; Nash, 2003).

19. It is analytically correct to draw an important distinction here between the first three mechanisms and the last two. $(\boldsymbol{M_A 1}), (\boldsymbol{M_A 2})$ and $(\boldsymbol{M_A 3})$ imply an instrumental conception of education as a positional good (its value depends on what the others do, the number who possess it, and its distribution); $(\boldsymbol{M_B 1})$ and $(\boldsymbol{M_B 2})$, by contrast, only involve a view of education as consumption good ('the more expensive it is, the less it will be bought'). I shall return to this point later.
20. The existence of these processes has also been well documented by the sociology of education. The existence of processes of type 1) has been widely discussed, though sometimes in conceptually cumbersome and inappropriate terms, by a copious, Marxist-inspired body of literature: Althusser (1970), Baudelot and Establet (1971), Bourdieu (1966, 1973, 1979, 1986), Bourdieu and Passeron (1967, 1972), and Bowles and Gintis (1973) are significant examples. Processes of type 2) and 3) have recently been described by the ethnographically oriented research of Stéphane Beaud (2003) as well as by Marie Duru–Bellat (2002). Mohamed Cherkaoui (1979, 1986) has especially emphasised the importance of the phenomena evoked in points 4) and 5). On this see also Duru-Bellat et al. (2004).
21. In this regard, note that in my model the matrix attributions for O_6 and O_7 on $\boldsymbol{M_A 2}$ as well as $\boldsymbol{M_A 3}$ are attempts to mathematically capture statistically improbable educational outcomes that nevertheless are sometimes present in social reality.
22. The model was estimated using the *Lem* program ('*Log-linear and event history analysis with missing data using EM algorithm*') written by Jeroen Vermunt of the University of Tillburg (see Vermunt, 1997). The estimation was performed by means of a specific type of maximum likelihood algorithm adapted to the log-linear non-hierarchical model: this being an algorithm known in the literature as a '*uni-demensional Newton algorithm*' (Vermunt, 1996: 27–28, 317–321; 1997: 5, 71, 89). The constraints of parameter identification were of the *Anova* type (Kaufman and Schervish, 1987; Vermunt, 1996: 10–12; 1997; Powers and Xie, 2000: 108). Also to be noted is that the results presented refer to the model estimated on data weighted by means of the procedure described in note 6. I also estimated model *[5]* as a weighted log-linear model (Vermunt, 1996: 29; 1997: 9). When this alternative strategy was used, the results did not change. The goodness-of-fit statistics for the model estimated under the form $(\boldsymbol{F_{ij}}) = z_{ij} * \boldsymbol{u} * \boldsymbol{u_i} * \boldsymbol{u_j} * \boldsymbol{u_{ijk}^{Ma.1}} * \boldsymbol{u_{ijk}^{Ma.2}} * \boldsymbol{u_{ijk}^{Ma.3}} * \boldsymbol{u_{ijk}^{Mb.1}} * \boldsymbol{u_{ijk}^{Mb.2}} * \boldsymbol{u_{ijk}^{Mc.1}} * \boldsymbol{u_{ijk}^{Mc.2}}$, where z_{ij} is the coefficient of weighting for the case i, j, are the following: $L^2 = 26.51$ (0.598); $Bic = -253.33$; $ID = 0.015$; $rL^2 = 99.26$; $L^2/dl = 0.91$.
23. This statistic was calculated as $2\sum^i [f_{ij}] \log[f_{ij}/F_{ij}]$ (Gilbert, 1993: 73; Vermunt, 1996: 21; 1997: 74; Wong, 2003b). The significance of this value can also be read relative to the saturated model (Powers and Xie, 2000: 15). In this case, L^2 is 0 because the observed frequencies are perfectly reproduced by the model: a value close to 25 for my specification shows that I have reproduced the observation data just as well as the saturated model does but with at least 29 independent parameters.
24. This measure can be approximated by L^2-[(*degree of liberty*) $*$ $(\log N)$], N being the sample size. The '*Bayesian information criterion*' (*Bic*) has been used by studies on social mobility in order to limit the effects of large sample size on test outcomes. The more negative the value, the more the model achieves inclusive quality between its number of parameters and adjustment to the data. This statistic was initially introduced by Raftery (1986a, b), who summarizes the discussion that arose around it in Raftery (2001). See also Powers and Xie (2000: 106–107).
25. This measure is calculated as $\sum^{ij} |f_{ij} - F_{ij}|/2N$ (Vermunt, 1997: 74). It is normally interpreted as expressing the proportion of cases misclassified by the model.

26. This index has been calculated here as $\{[(L^2)_{\text{ind.}} - (L^2)_{\text{top.}}]/(L^2)_{\text{ind}}.\} * 100$, which is equivalent to $1-[(L^2)_{\text{top..}}/(L^2)_{\text{ind.}}]*100$. This statistic is often used in studies of social mobility in order to evaluate the extent to which M reduces the discrepancy between the theoretical data produced by model M' taken as reference and the observation data. Erikson and Goldthorpe (1992: 88–99 and note 19) discuss the significance of this measure in the context of log-linear models.
27. The [L^2/(number of degrees of freedom)] ratio as a goodness-of-fit measure is systematically discussed by Wong (1994, 2003b).
28. I thus adopt the strategy recommended by Powers and Xie (2000: 145–146): i.e. studying the behavior of a plurality of fit statistics instead of stopping at the value of one or, at best, two measures.
29. The mathematical form of this type of residual is $r_{ij}=[f_{ij}-Fij]/\sqrt{F_{ij}}$. It normally follows a normal distribution with a mean of 0 and a standard error less than 1, if the model is correct (Di Franco 2003: 86). It is often admitted that a value above 2 indicates a mis-adjustment of the model to the empirical data (Cobalti, 1992: 136; Gilbert, 1993: 85). Gilbert (ibid.), however, notes that this rule is only truly relevant to a residual form that follows a standardized normal distribution: on dividing the standardized residuals by their standard error, one obtains a residual form (adjusted residuals) satisfying this condition (if the model is correct). I have also calculated this type of residual. The results remained unchanged: all values were less than 2.
30. So that the scope of my results is correctly understood, I would stress that my analysis does not address the possible fit variations of the model produced by important variables such as gender or birth cohort. This is no doubt a shortcoming: I have decided to concentrate on my model's construction and global test. Some of the results not reported here – available from the author on request – show that the model fit withstands introduction of the variable 'gender'. I am also examining the possibility of combining my topological specification with log-multiplicative components in order to conduct parsimonious analysis of the temporal variations in the effects of the 'mechanisms postulated'.
31. This result was already visible in the parameter values of the complete version of topological models *[5], Table 9, part B*: the negative effect of $u_{ij}^{Mb.2}$ was nearly 1.6 times greater than that of $u_{ij}^{Mb.1}$. Moreover, this specific comparison gives me the opportunity to specify that I have not evaluated the relative importance of different parameters by this means because this would have required numerous comparisons without supplying a stable term of reference. Given that direct comparison of parameter values have been excluded *a priori* because of the well-known problems of interpreting log-linear parameters (Erikson and Goldthorpe 1992: 182–186), I have opted for the solution discussed above. See Stier, Grusky (1990: 743–744) for a clear application of the same strategy.
32. In light of what we have just said, Cherkaoui's epistemological evaluation (2000: 136, note 1) of Goldthorpe's first works (1980) is more correct: unlike Pawson, Cherkaoui – who explicitly confronts the latter on this point – denies that this type of research is related to generative mechanisms methodology.
33. The literature on the application of simulation methods in the social sciences has burgeoned since the end of the 1980s. On the specific point at issue here (the relation between mechanisms and simulation models) see, among others, Edling (2002: 213), Gilbert, Troitzsch (1999: 17), Goldthorpe (2000, chap 9: 158), Halpin (1999: 1500, 1501, 1503), Hanneman, Collins, Mordt (1995: 3, 4, 28, 29, 40), Heise (1995), Macy, Willer (2002: 162). More generally, Fararo, Hummons (1995), Moretti (2000, 2002), and Sawyer (2003) conduct very useful discussion on the application of simulation

models in sociology. I myself have attempted a critical analysis of this copious literature (Manzo, 2004b, 2005).

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