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Democratization of educational systems, inequality, opportunity, and selection process: a re-examination of the case of France

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ABSTRACT

The research brought forward examines the evolution of the selective social processes that have accompanied educational expansion over the long term, referring to the case of France. It is based on an original index which addresses the issue of assessing inequality within the selection process for access to various educational levels. The results obtained support an understanding of contradictory prior findings attached to the thesis of uniform democratization and the thesis of "qualitative" or "intrinsic" democratization, respectively. They substantiate a new, alternative thesis, that of "contradictory democratization", according to which the effects of socioeconomic changes, and the correlative integration of the educational system, have tended to counterbalance the negative effects of educational policies on the relative achievement of children from disadvantaged backgrounds.

Introduction

Assessing educational policies and interpreting observed trends raises the problem of comparing inequality of opportunity between populations with different distributions of social subgroups and educational levels. This problem has fascinated generations of analysts of inequality. There are just as many ways of solving it as there are ways of conceiving of inequality between social subgroups. However, as far as the evaluation of democratization policies is concerned, once the problems posed by "quantitative" democratization – that is, increasing participation at higher levels – have been overcome to a large extent, we turn our attention to a new, specific object. We want to evaluate the qualitative or intrinsic aspect of the democratization process – that is, the genuine effects of social origins after controlling for marginal changes (variation of social origins distribution and opening up of educational levels). For instance, in an intertemporal comparative perspective, we wonder if the social groups which had the lowest level of access to education in the system's previous state have progressed relatively better than the others, *ceteribus paribus* – margins variation not being taken into consideration. This question itself refers to two different issues. The first issue is related to intrinsic changes in the social structure of opportunity for access to various

educational levels (i.e., intrinsic association between variables) on the basis of indices which are insensitive to the distributions of margins.[1] The second issue is related to intrinsic inequality of the generative mechanisms of selection, in the broadest sense. This intrinsic inequality includes all processes the effects of which influence the opportunities of access to the educational levels under consideration, independently of the mathematical effect of the opening up of these educational levels. This type of inequality is identified as inequality within the selection process.

Linear regressions, educational transition models, and log-linear models may offer responses to the first problem posed, that of inequality of intrinsic links between educational stratification variables and social stratification variables. Bulle (2016) proposed a measure in response to the second problem which may better capture the genuine sense of intrinsic or qualitative democratization, that of inequality within the selection process. On the basis of this new method, this article proposes to reassess the empirical evidence concerning the democratization of the French educational system, from a long-term perspective (using cohorts born from 1910 through to 1979). The results obtained will serve to better understand the qualitative effects of educational policies over the long period under consideration.

In the following section, some comments on the various methods implemented to date to assess the intrinsic evolution of the democratization process are proposed. Then, using Bulle's (2016) index and nationally representative surveys, the changes in inequality within the selection process that occurred with schooling expansion over the course of the 20th century are examined in the case of France. This examination is used to test competing previous theses regarding the evolution of the intrinsic selective social processes accompanying the expansion of educational systems. The results obtained support an understanding of contradictory prior findings attached to the thesis of "uniform" democratization (i.e., no change in the effects of social origins) and the thesis of qualitative or "intrinsic" democratization (i.e., equalization of the effects of social origins). They substantiate a new, alternative thesis, that of "contradictory" democratization, according to which the counter-productive role of educational policies contradicts the equalizing role of socioeconomic changes.

Comments on various methods for assessing the intrinsic change of the democratization process

Three main types of methods have been used to date to assess the intrinsic change of the democratization process: (1) linear regressions, (2) educational transition modeling, (3) log-linear modeling. To these methods can be added the measure of inequality within the selection process (4).

Linear regressions (1) represent classic statistical approaches for studying the association between two continuous variables (a social background variable, characterized by a scale of prestige, income, or educational attainment, and a schooling destination variable, i.e., educational attainment measured as the number of school years completed). One limitation of this method is that the explained (continuous) variable, measuring educational attainment, does not allow differentiation of the nominal levels of education in play.

Educational transitions modeling (2) was proposed by Mare (1981, 1980). Formal schooling is conceptualized as a sequence of transitions between grades. For each level of schooling considered, the model considers only those people who reach this

level, and analyses social background effects on school continuation (grade progression) – that is, following a sequence of the subpopulations concerned. Background effects are measured on the basis of a set of logit regressions: Linear and additive effects of exogenous variables on the log odds of making each transition are estimated. In this model, inequality of opportunity regarding access to a particular educational level is not affected by the impact of background over all previous transitions.

One variant is the ordered logit model (Breen, Luijkx, Müller, & Pollak, 2009). Here, the log odds ratio compares opportunity of exceeding, rather than failing to exceed, the various levels of education, according to social backgrounds. It is supposed to be the same at all levels of education and has the particularity of being independent of the thresholds themselves. It is advantageous when it is impossible to rely on comparable thresholds between two populations. Like the linear regression model, the ordered logit model presents the drawback of not differentiating diagnoses for each of the educational levels under consideration.

Log-linear modeling[2] (3) of contingency table data is based on hypotheses on the association structures, in terms of odds ratios,[3] or certain functions of them, which link the variables of successive contingency tables. The results predicted by these models (expected figures position by position) are compared to observed figures. For example, the "null hypothesis" can be tested between two or more periods. According to this hypothesis, marginal distributions of origins and destinations change over time, but the odds ratios calculated for any pair of categories of origins and for any pair of categories of destinations remain invariant over time. Another hypothesis may explore the possibility that the odds ratios underlying the two mobility tables are uniformly closer to the value of 1, which would translate a general shift towards equality.

One major drawback of indicators derived from Methods 1, 2, and 3 is that the significance, in terms of relative positioning, of the various educational levels varies with the part of the population acceding to them. However, this problem is not inherent to the methods at stake because it is possible to define educational attainments by considering education as a positional good. This can be addressed by referring to, for instance, the educational attainments discriminating the top 10% of the population, the following 10%, and so forth, but, usually, the opportunity distribution in question can only be approximated (Bukodi & Goldthorpe, 2016, pp. 6, 11).

Inequality within the selection process (4) for access to a discrete good G, one educational level, for instance, supports the analysis of intrinsic changes in inequality regarding the microsocial processes of selection. By definition, this measure interprets educational opportunity as a positional issue. Therefore, it involves a fixed reference frame of relative opportunity (i.e., opportunity intervals as deciles). The principle of the measure we will rely on (developed in Bulle, 2016) can be described as follows. The results of the selection process for access to the good G in play, not taking into account the opening up of access to G, can be represented by a hypothetical classification of the individuals within the population according to their relative opportunities of access to G, in a reference frame independent of the variation of overall access to G. Effective access to G is assumed to be the result of the access priorities indicated by this hypothetical classification and the availability of G. The measure in question is based on a model of the latent classification of the individuals within the population under consideration. It is assumed that this classification underpins the results offered by the joint distribution of

class origins and access to the nominal level of education *j* at stake. Inequality (in respect of a variable *i*, social group, gender, nationality, etc.) within selection represents a measure of the inequality of this classification and will be identified in the following as "$\tilde{a}_g$".[4] The model is based, as is often the case in statistics, for instance, on the construction of a straight line used to characterize the links between variables. The straight line segment in question here is not a regression line but a heuristic construct, aiming to assess the situation of inequality. It permits comparisons by regularly spreading the discrepancies in the selection process results (social groups' access to *G*) across a virtuous continuous distribution of relative opportunity (the percentile ranks). The index $\tilde{a}_g$ represents the slope of this straight line segment (see Appendix 1).

As is the case for odds ratios, this measure is insensitive to margins. Moreover, this measurement method presents the advantage of allowing the study of what occurs at each of the nominal educational levels considered, where specific selection processes may operate, while relying on a fixed reference frame of relative opportunity. It has highly significant inter-temporal and inter-societal comparative potential, but in this respect, it only differentiates two aggregated social groups: the disadvantaged group, which brings together the social subgroups whose access to the good *G* under consideration is inferior to the average for the population, and the advantaged group, which brings together the social subgroups whose access to the good *G* under consideration is superior to the average.

Hypotheses on the evolution of selective social processes

We can distinguish in the literature today two major theses on the evolution of selective social processes during the expansion of educational systems, and this article will add a third alternative hypothesis: (A) the thesis of stability (or "uniform democratization"), (B) the thesis of the progress of qualitative or intrinsic democratization, and (C) the alternative thesis of contradictory democratization.[5]

The thesis of stability (or "uniform democratization") (A) may be related to the model proposed by Raymond Boudon (1974). This thesis accounts for the following phenomenon: In a context of stable social stratification, the reduction of inequality of educational opportunity associated with the expansion of schooling can have no significant impact on social mobility.

To conduct his demonstration, Boudon (1974) simulates the educational transitions using congruent hypothetical data with available empirical data. Furthermore, the process of allocation of positions is quasi-meritocratic: It is based mainly on the level of education attained. The resulting absence of impact from educational expansion on social mobility – when the social structure does not change – thus reflects the uniform character of democratization. This can be shown by the fact that the rates of access to the various percentile ranks of the student population remain approximately stable in the model (Bulle, 2009). From there, the opening up of the various nominal educational levels leads to a reduction of the inequality of opportunity regarding each educational transition, as measured by various classical indices, which does not induce a lowering of the inequality of social opportunity. To explain overall educational inequalities, Boudon invoked in particular the recurrent impact of individual social positions on their situations of choices and, especially, their relative levels of satisfaction.

Subsequent sociological works related to the hypothesis of uniform democratization have been in line with Boudon's (1974) model. Breen and Goldthorpe (1997) based their explanation on the socially differentiated behaviors related to aversion to the risk of downward social mobility. Besides, the hypothesis of uniform democratization was fuelled by a substantial number of empirical studies. The influential collective work *Persistent Inequality* (Shavit & Blossfeld, 1993) proposes analyses carried out in 13 countries, systematically using linear regression methods and analysis of educational transitions following Mare's (1980, 1981) model. The results reveal that all the countries, except for Sweden and the Netherlands, exhibit stability of socioeconomic inequalities of educational opportunities. The hypothesis is presented in a "weak version" by Shavit, Yaish, and Bar-Haim (2007), on the basis of a review of literature on the subject, in which inequalities potentially decrease in terms of completion of the lower educational levels and in the mid-20th century.

The thesis of intrinsic democratization (B) takes root in the modernization hypothesis developed in the analysis carried out by Blau and Duncan (1967). According to this thesis, industrial societies are governed by principles of efficiency which are independent of the particular values of social groups. In other words, industrialization secures for schools an enhanced role in the allocation of social and professional statuses, and engenders a rationalization of selection criteria.[6] However, the thesis of modernization assumes that, from the moment when social mobility is relatively substantial, it is plausible that it might remain fairly stable. Open competition for the acquisition of social statuses maintains the satisfaction of social actors. In line with the modernization thesis, Treiman (1970) defended that we may expect that industrialization enhances intrinsic social mobility by breaking down the rigidity of the class structure of traditional society, especially through the impact of various factors on the reduction of status differences in attitudes and behavior regarding education (e.g., more extensive schooling, more pervasive mass communications, greater urbanization, and increased geographical mobility).

Breen et al. (2009) proposed a re-examination of the results presented in *Persistent Inequality* (Shavit & Blossfeld, 1993) for eight European countries, based on an analysis of educational transitions according to the ordered logit model as well as Mare's (1980, 1981) model. They studied the case of boys born between 1908 and 1964, and found a widespread decrease in educational inequality in Sweden, the Netherlands, Britain, Germany, and France, while the cases of Italy, Ireland, and Poland were less obvious. Such decline mostly took place in the middle of the century, between birth cohorts 1908–1924 and 1945–1954, and thus concerned what happened in educational systems before the mid-1970s. The most significant and extensive decrease in inequality concerns children from farming and working-class backgrounds. According to the authors, it is understandable that we observe a declining association between class origins and educational attainment due to the convergence in this sense of economic and educational factors. Among them, they identify the substantial improvement of general living conditions in the decades of economic growth and welfare state expansion following World War II and, also, changes within educational institutions including the growth in public provision of early child care and preschool education, the development of full-day rather than part-time schooling, increased schooling support to counteract students' performance gaps, differences in the timing, extent, and manner of tracking, and so

forth. Moreover, secondary education became free, and the length of compulsory schooling was extended. Further factors they mention involve other consequences of economic growth, including the reduction in family size and, correlatively, the increase of the real average family income and decreasing pressure on children from disadvantaged backgrounds to contribute to the family income as early as possible.

Nevertheless, the positive results obtained by Breen et al. (2009) are mitigated regarding the last birth cohort 1955–1964. Moreover, Barone and Ruggera (2018) reassessed their conclusions for a larger number of countries and extended them by adding the birth cohort 1965–1980. They confirmed these conclusions but observed that, for students in the last two birth cohorts, 1955–1964 and 1965–1980, who acceded to education in a period of deployment of educational democratization policies, the declining trend of inequality of educational opportunity slowed down, or even stopped for most European countries.

Considering the mixed results obtained for the last cohorts studied, it may be instructing to study more precisely intrinsic change affecting the generative mechanisms of selection. In this perspective, we must capture inequality within the selection process.[7] Let us assume as an outcome the maintenance of intrinsic inequality, as it was supported in previous works which, nevertheless, did not assess either inequality within the selection process. Then, the certain positive effects of the socioeconomic factors evolution on the relative situations of children from disadvantaged backgrounds would lead us to advance a third thesis (C).

The thesis of contradictory democratization (C) defends that socioeconomic changes and institutional changes have had, overall, opposite effects on intrinsic, or qualitative, democratization. According to this hypothesis, we can no longer speak, in relation to (A), of the ineffectiveness of educational policies when confronted with the role of social structures, and even less, in relation to (B), of the equalizing role of these policies. The contradictory democratization thesis maintains that, overall, the counter-productive effect of educational policies neutralized the equalizing effect of socioeconomic changes.

Theses (A) and (B) above refer to hypotheses that are now old and do not, or not sufficiently, take into account the institutional transformations of education, or else assume, like the modernization thesis, that the latter pertained to a rationalization of the education process. Developments in sociology of education from the late 1970s revealed the possible paradoxical effects of educational reforms by bringing to light the importance of institutional effects on educational opportunity. In the words of Coleman (1990, p. 29), the relative intensity of the convergent school influences and the divergent out-of-school influences determines the effectiveness of the educational system in providing equality of educational opportunity. In the present context of analysis, we may infer that, while school expansion and socioeconomic change should lessen divergent out-of-school influences, convergent school influences decrease when school develops less challenging and less explicit norms of educational achievement and knowledge and, correlatively, when the opacity and heterogeneity of the educative system increases (Cherkaoui, 1979; Coleman, Hoffer, & Kilgore, 1982; Halsey, Heath, & Ridge, 1980; Reynolds et al., 2014; Rutter et al., 1979). This is the path that educational reforms have taken in a very general way by conflating democratization and massification – that is, by weakening the pedagogical mission of schools.

Changes in inequality within the selection process over the last century in France

The French education system

The case of France offers a typical example of the evolution of formal education in Western educational systems with the expansion of schooling which, moreover, has been particularly well described by large-scale surveys periodically conducted over the last 50 years.

Until the late 1950s, France had a traditional European dual-track system differentiating primary and selective secondary education. The integration of the primary and secondary educational levels was endorsed by making school compulsory until the age of 16 instead of 14 (this reform took effect in 1967). The previous system of separated educational institutions was progressively replaced in the 1960s by a streaming system within the *collège* (junior high school) and, in 1968, a 2-year common core was instituted. The following reforms progressively removed the entire streaming system, from the end of the 1970s and during the 1980s and 1990s, whilst the repeating of academic years was considerably reduced. After the resulting period of common core study (covering mainly the first 5 years of secondary education), the school population separates between vocational tracks and the preparation for a general, technical, or vocational baccalaureate, each one being divided into streams of study according to various specializations. Figure 1 illustrates the quantitative development of these general, technical, and vocational baccalaureates at the *lycée* (high school) level during the 20th century. Technical and professional baccalaureates were created rather late and replaced lower level diplomas with the extension of school attendance. The structural evolution of the French school towards a unified and integrated educational system has been accompanied by dramatic changes in educational curricula and teacher training. As in most other Western education systems, if we consider what happened in the long term, these changes were supposed to support educational democratization by weakening standards of an academic nature (in the sense of an explicit and structured form of teaching) and giving priority to the socializing mission of schools.

The case of France: previous analyses of democratization

Studies on educational democratization in France mostly use log-linear models of contingency tables, but also linear regressions, logistic regressions, educational transition models, and simple odds ratios calculations. All of the analyses in question make very general use of the Training and Occupational Skills (*Formation et Qualification Professionnelle: FQP*) surveys which were conducted by the French National Institute of Statistics and Economic Studies (INSEE) in 1964, 1970, 1977, 1985, 1993, and 2003. They use one or several surveys and may or may not be based on the constitution of birth cohorts. These surveys, which offer respondents' detailed information on their schooling career, training, family background, and so forth, make France's educational system an interesting candidate for analyzing long-term changes in inequality of educational opportunity over schooling expansion and democratization policies. Beyond the very mixed results obtained
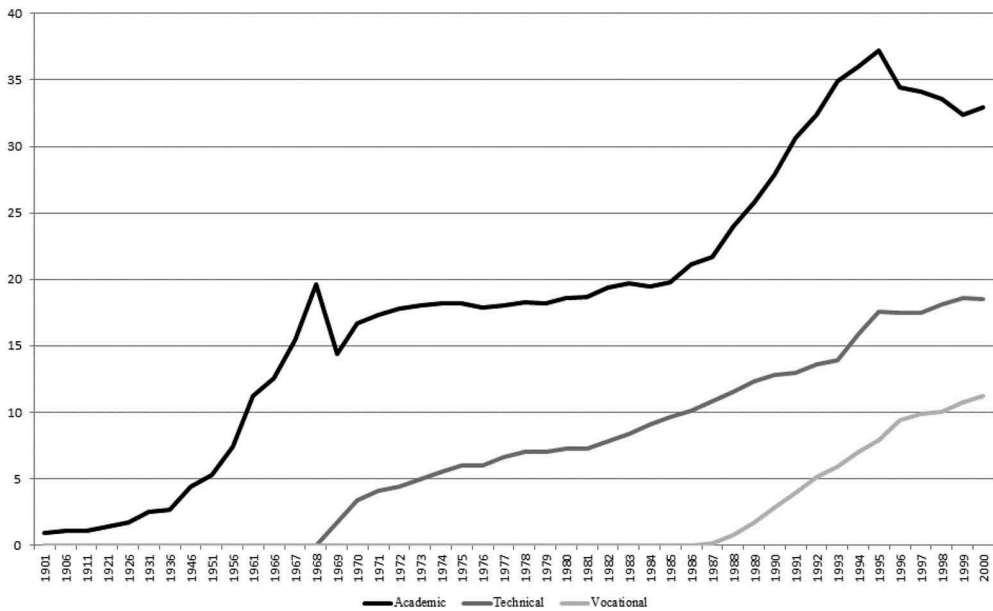
Figure 1. Fraction of holders of a baccalaureate degree in a generation (%).

Source: Ministry of National Education.

at first sight, which are not attributable to the (particularly homogeneous) data sources, we can distinguish relatively convergent diagnoses for a certain number of points.

Several analyses, based on log-linear models, detected no firm trend towards increasing or decreasing inequality of educational opportunity in French society (Garnier & Raffalovich, 1984; Goux & Maurin, 1995). Nevertheless, more sophisticated models (Breen et al., 2009; Smith & Garnier, 1986; Thélot & Vallet, 2000, 2004) reveal a general advancement of intrinsic democratization. But this progress presents a considerable limitation: It is principally the effect of the improvement of the relative position of women and all individuals from farming backgrounds. It reflects the evolution of investment in education for these groups. If we only consider the relative opportunities for individuals from non-farming backgrounds, it appears that these have changed little in the long term (Vallet & Selz, 2007), and this is even truer for boys. Furthermore, another limitation of the results obtained is the change in significance of the educational levels brought into play in the models. Duru-Bellat and Kieffer (2000) observe that, alongside educational expansion in France, the selection process was just shifted to higher levels, and at these levels, the social pattern of transition rates remained unchanged. Other studies reveal that such a shift in the selection process had negative impacts on relative educational opportunities: The deterioration of the value of the lower educational levels is detrimental to the most academically fragile (Coutrot & Kieffer, 2009). Moreover, the raising of formal educational levels occurred partly due to vocational paths of postsecondary education being mostly taken by boys and girls from disadvantaged backgrounds (Givord & Goux, 2007).

In all, the analyses carried out reveal no general progress, in the sense of intrinsic democratization, that might be attributed to educational policies. Nevertheless, for approximately two decades, the image dominating literature and linked to the above-mentioned

works is that of a small but real intrinsic reduction of inequality of educational opportunity in France, and correspondingly that of a qualitative or intrinsic democratization of schooling.

Data and variables

The present analyses are based on the important source of nationally representative data proposed by the Training and Occupational Skills (*FQP*) surveys which were conducted by the French National Institute of Statistics and Economic Studies (INSEE)[8] in 1970, 1977, 1985, 1993, and 2003 and which we referred to above. We limited the sample for each survey to individuals aged over 25 and under 65 and to French individuals only, in order to minimize the presence of people who had not spent at least the greater part of their schooling in France. The samples present in 1970, 1977, 1985, 1993, and 2003 are composed, respectively, of 17,356, 17,172, 16,938, 7,086, and 14,834 men and 8,848, 11,178, 12,110, 7,456, and 16,599 women.

Based on these five surveys, the measurement of the coefficient of inequality of opportunity within the selection process was carried out by constituting six 10-year birth cohorts: 1910–1929,[9] 1930–1939, 1940–1949, 1950–1959, 1960–1969, and 1970–1979.[10]

Furthermore, the INSEE class schema distinguishes six main active social subgroups[11]:

(1) farmers and smallholders;
(2) artisans and shopkeepers;
(3) higher grade professional, large employers, administrative & managerial occupations.
(4) intermediate occupations (lower grade professionals, administrators and officials, higher grade technicians, managers in small business and industrial establishments);
(5) employees (routine non-manual employees in administration and commerce, sales personnel, and other rank-and-file service workers);
(6) manual workers (skilled manual, semi- and unskilled manual workers, and agricultural workers).

Contingency tables have been built in relation with opportunity of access to the various educational levels Lj considered, on the basis of which the changes in inequality within the selection process "$\tilde{a}_g$" could be analyzed.[12] As indicated in the section on comments on various methods for assessing the intrinsic change of the democratization process, this inequality involves the aggregate set of social subgroups where individuals' opportunity of access to an educational level under consideration, Lj, is lower than the overall proportion of individuals attaining Lj. $\tilde{a}_g(Lj)$ represents the general level of inequality within the selection process for access to Lj. The various educational levels which will be considered are indicated in Table 1.

The changes over time in the relative opportunities of the children of land-owning farmers are in large part the consequences of economic development and the shift away from agriculture. In order to better capture the effects of educational policies, in the following, the evolution of inequality within the selection process is analyzed without taking them into account.[13]

Table 1. Classification of educational levels.

Educational Level	
L_V	Diploma in vocational education inferior to the baccalaureate level or diploma certifying the end of the first cycle of secondary education.
L_{IV}	Baccalaureate, or a vocational *brevet*, or another diploma of the same level (second cycle of secondary education, general, technical, or vocational).
L_{III}	Diploma in higher education, at the minimal level equal to baccalaureate plus 2 years.
L_{II}	Diploma in higher education, at the minimal level equal to baccalaureate plus 3 years.
L_I	Diploma in higher education, at the minimal level equal to baccalaureate plus 5 years.

Overall changes in inequality within selection for access to various educational levels

If we exclude the children of land-owning farmers from the population base, the five main observations that follow can be made (see Tables 2 and 3).

  (1) Concerning boys, inequality within the selection process for access to the education level L_{IV} (baccalaureate level, general, technical, or vocational, Table 2) remained particularly stable during the period under consideration, while the average rate of access to level L_{IV} rose from 14% to 56%.
  (2) Concerning girls, inequality of opportunity within selection for access to educational level L_{IV} decreased over the 20th century. This is consistent with observations made throughout the Western context of schooling expansion (Shavit &

Table 2. Inequality of opportunity within selection for access to level L_{IV} education. French, from 25 to 65 years old, sons and daughters of land-owning farmers not included.

	Boys		Girls	
	Average rate of access (%) x_j	Inequality coefficient $a_g(L_{IV})$	Average rate of access (%) x_j	Inequality coefficient $a_g(L_{IV})$
1910–1929	14	0.69	9	0.85
1930–1939	19	0.73	15	0.74
1940–1949	27	0.72	24	0.71
1950–1959	26	0.75	31	0.73
1960–1969	35	0.73	41	0.67
1970–1979	56	0.72	65	0.60

Source: FQP surveys by INSEE for 1970, 1977, 1985, 1993, 2003.

Table 3. Inequality of opportunity within selection for access to level L_{III} education. French, from 25 to 65 years old, sons and daughters of land-owning farmers not included.

	Boys		Girls	
	Average rate of access (%) x_j	Inequality coefficient $a_g(L_{III})$	Average rate of access (%) x_j	Inequality coefficient $a_g(L_{III})$
1910–1929	6	0.86	4	1.06
1930–1939	9	0.85	6	0.91
1940–1949	15	0.77	13	0.82
1950–1959	15	0.79	17	0.76
1960–1969	21	0.77	24	0.71
1970–1979	37	0.77	44	0.60

Source: FQP surveys by INSEE for 1970, 1977, 1985, 1993, 2003.

Blossfeld, 1993). This decrease began from a more unequal starting point than the starting point for boys and reaches a less unequal level (Table 2). Given the stability of inequality within selection for access to the education level L_{IV} for boys, it cannot be attributed to changes that affected boys and girls at school in a similar way (e.g., educational changes) but to changes involving an interaction between gender and social variables, such as those affecting girls' occupational projects after 1945.

(3) Concerning both boys and girls, inequality within selection for access to education level L_{III} (higher education diploma, Table 3) has lessened since the beginning of the 20th century, reaching a value close to that of the inequality within the selection process for access to education level L_{IV}. This convergence of levels of inequality appears to be an effect of the changing function of higher education in the overall educational system structure. The growing and endogenous investment in education[14] and the decrease in the social value of secondary school diplomas explain a displacement of expectations toward the higher levels of education. On these bases, the observed decrease of inequality within selection for access to higher education mainly reflects the change in the relation disadvantaged families have with higher education.

(4) Concerning boys, this decrease is limited to the birth cohort 1940–1949. It therefore concerns the first cohorts of students whose entire schooling took place during the post-war period.[15] This tailing off of inequality is prior to the first post-war democratization reforms of secondary education.[16] After inequality within the selection process for access to education level L_{III} came closer to inequality within the selection process for access to educational level L_{IV}, it remained stable. This is not a necessary, but a consistent result, since inequality within selection for access to educational level L_{IV} remained stable itself, and access to level L_{IV} is a condition for access to level L_{III}.

(5) Concerning girls, the significant decrease of inequality within the selection process for access to education level L_{III} (higher education diploma) marked by the birth decade 1970–1979 (Table 3) is, first and foremost, the result of the development of short streams of study in higher education that are not reserved for the holders of a "general" baccalaureate: Inequality within the selection process for access to a general baccalaureate for girls diminished only slightly between the last two decades of birth, from 0.68 to 0.65. These observations show that the progress of intrinsic democratization observed here mainly reflects the change in the relative investment in education of girls from disadvantaged social subgroups.

Intrinsic variations of the selection process results

Up to this point, we relied on a measure of inequality within the selection process for access to given levels of education Lj. Therefore, we had a binary (access/no access) variable and we used an index that allowed us to compare inequality within the selection process for access to these nominal levels Lj. If the social biases affecting access to each educational level Lj considered were identical, the $\tilde{a}_g(Lj)$ coefficients would be equal. It would be as if the observed results of access to the nominal levels

of education were derived from a single virtual ranking of individuals from the whole population according to their relative educational opportunity, and the opening up of these different educational levels. We have seen that this is not the case. The higher the educational levels under consideration, the more inequality increases. Nevertheless, the evolutions reveal a narrowing of the value of the various $\tilde{a}_g(Lj)$ coefficients. It is interesting to examine the evolution of inequality within the selection process, not regarding specific educational level, but percentile ranks within the school population, in order to have a global picture of the evolution of the selection process's intrinsic results. In this perspective, we can consider education as a continuous good and try to apprehend the function $\tilde{a}_g(x)$ identifying inequality within the selection process for access to each level x of attainment opportunities (i.e., identifying the top 100x% of the school population).

To apprehend the function $\tilde{a}_g(x)$, we referred to different strictly hierarchical educational levels Lj. The overall rate of access to Lj being x_j. $\tilde{a}_g(Lj)$ reveals the intensity of inequality $\tilde{a}_g(x_j)$ within the selection process for access to the top 100x_j% of the school population. We considered the education levels L_V, L_{IV}, L_{III}, L_{II}, and L_I, with L_I – representing access to an educational level greater than or equal to the baccalaureate level plus 5 years – being retained only for the birth cohort 1970–1979. Inequality within the selection process for access to various subgroups of the school population with the best educational opportunity (on X axis) of the school population were obtained by approximation, using for $\tilde{a}_g(x_j)$ (on Y axis) a moving average between education levels Lj whose opening is x_j. As inequality within the selection process $\tilde{a}_g(x)$ tends to rise when x_j diminishes, we expect decreasing curves.

Note that the younger the generation, the wider the percentile spread. This is an effect of the expansion of secondary education: Access to the first (nominal) educational level taken into account here, a L_V level (first diploma of secondary education, general or technical), concerned the top 30% of the school population in the first birth cohort (1910–1929) and the top 84% in the last birth cohort (1970–1979).

The results are the following:

(1) Concerning boys and girls, for a given cohort, the curve $\tilde{a}_g(x)$ is downward, marking increasing inequality as greater educational opportunities are identified. But the function $\tilde{a}_g(x)$ tends, from one birth decade to another, to get closer to a horizontal straight line ($\tilde{a}_g(x)$ = constant): The equalization of the level of inequality within the selection process for access to the various percentile ranks of the school population reflects the overall integration of the educational system (Figures 2 and 3).

(2) Concerning boys, what is remarkable is that this harmonization, characterizing changes in the selection process and accompanying the expansion of the educational system, is based on a high level of inequality within selection (Figure 2). While the social inequality of educational choices diminished with the increasing integration of the educational system, inequality within selection for access to the lowest level of education increased, especially for the last cohort 1970–1979. This, first and foremost, reflects the increase in inequality within selection for access to the education level L_V (a first diploma of secondary education, general or technical). Therefore, boys from the families of manual workers (here, they constitute the whole group with a below-average access to L_V) have benefited relatively less than the others from
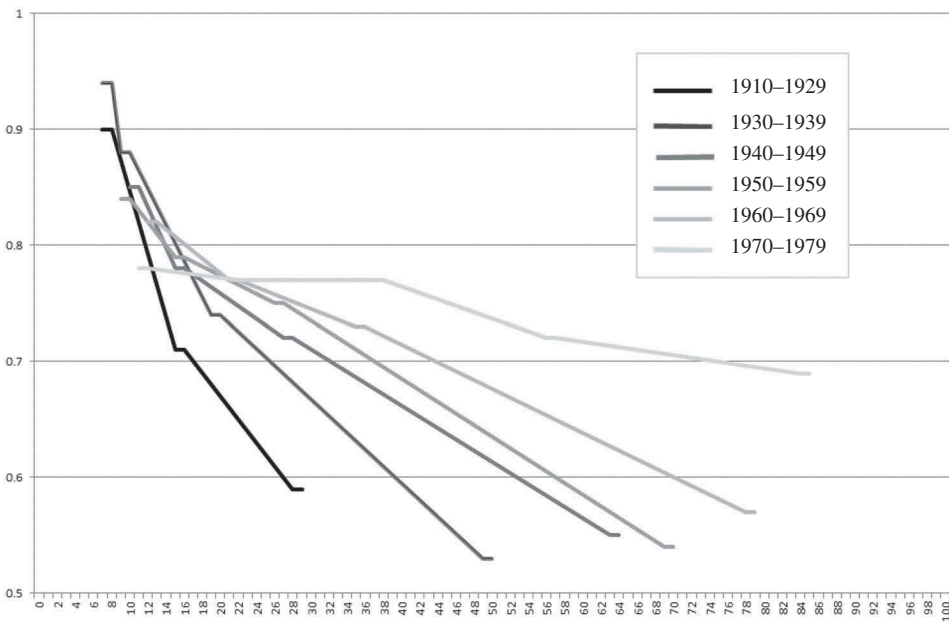
Figure 2. Inequality within selection for access to the various percentile ranks of population. French boys, from 25 to 65 years old, sons of land-owning farmers not included.

Source: FQP surveys by INSEE for 1970, 1977, 1985, 1993, 2003.

Note: Curve 1970–1979 shows that inequality of access to the top 85% of the school population is equal to 0.69, while inequality of access to the top 10% is equal to 0.78.

school expansion, especially because access to a first vocational diploma was formally raised. This corroborates the diagnosis of Coutrot and Kieffer (2009, p. 75). The situation of the various curves in relation to a given percentile rank show no clear trend for access to the top 15–20% of the population, but comparisons are difficult in this first interval. By contrast, below the top 20%, the curve corresponding to birth cohort 1970–1979 dominates all the others, showing a considerable accentuation of intrinsic inequality within the selection process. One major explanation is that, in order to be part of, for instance, the top third of the school population, boys in the 1910–1929 birth cohort had to have completed a first diploma of secondary education, general or technical, and boys in the 1970–1979 birth cohort had to have completed a first higher education diploma.

(3) Concerning girls (Figure 3), the quasi-superposition of curves on the intervals where results can be compared reveals the relative stability of the selection process for birth decades from 1910–1919 to 1960–1969. A clear homogenization of the selection process is observed for the next cohort, 1970–1979, which is reflected in a stable level of $\bar{a}_g(x)$ up to the first quarter of the population whose opportunities are greatest, and then a slight increase in the level of inequality beyond. Unlike the case of boys, however, the integration of the educational system and the harmonization of levels of inequality are based on the level of the lowest inequality – inequality within the selection process for access to a first
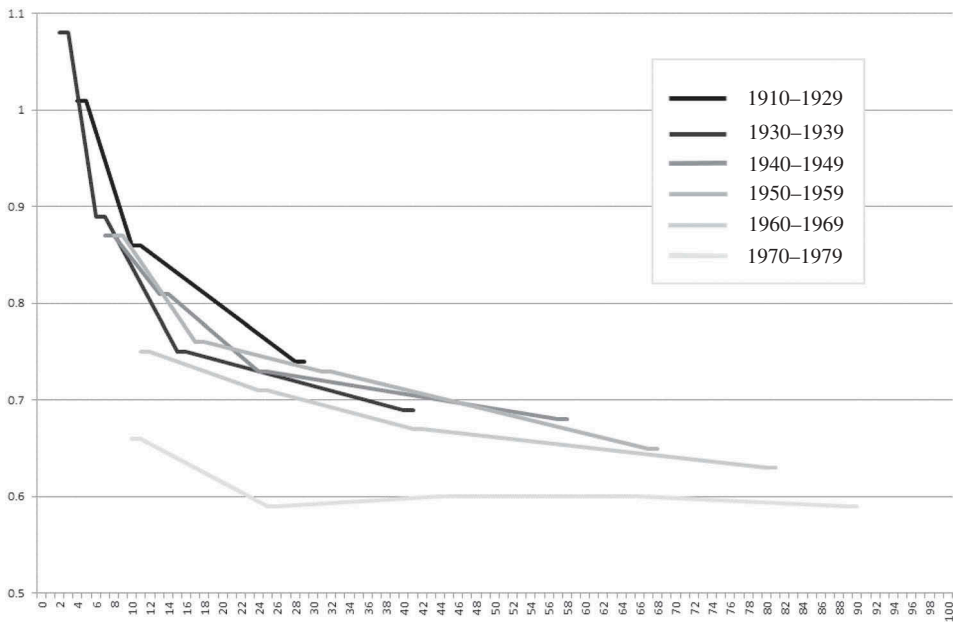
Figure 3. Inequality within selection for access to the various percentile ranks of population. French girls, from 25 to 65 years old, daughters of land-owning farmers not included.

Source: FQP Surveys by INSEE for 1970, 1977, 1985, 1993, 2003.

Note: Curve 1970–1979 shows that inequality of access to the top 90% of the school population is equal to 0.59, while inequality of access to the top 10% is equal to 0.66.

diploma of secondary education – which, moreover, and contrary to the case of boys, decreased over the period covered by the various birth cohorts.

Major findings and discussion

This article aimed to reassess the meaning of the democratization of the French educational system by using a vast dataset made up of five national surveys, and a method capturing the intrinsic results of generative mechanisms of inequality – inequality within the selection process. The major findings are the following:

(1) Quantitative democratization did not have, overall, a visible effect upon intrinsic democratization – inequality within the selection process here – that might, for example, have been imputed to the socializing effects of social mixing or, in line with the hypothesis of maximally maintained inequality (Prost, 1986; Raftery & Hout, 1993), to an eventual lack of sufficient candidates eligible for selection from advantaged subgroups, past a certain point, necessitating a recourse to less advantaged social strata.

(2) The integration of the educational system led to the harmonization of the level of inequality within the selection process, making it more and more independent of the levels considered. This evolution means that there is no more increase in

inequality within the selection process when we go from one level of education to another, which shows that situations of educational choice have come closer. Hence, the third finding:

(3) The overall decrease of inequality within the selection process in the case of girls, and the decrease of inequality for access to higher education in the case of boys from the birth cohort 1940–1949, may be mainly explained by a decline in the effect of socio-economic inequalities on educational choices (Boudon, 1974; Goldthorpe, 1996).

(4) Ultimately, if one refers to access to educational level L_{IV} (baccalaureate level), and if we disregard the evolving economic role of girls and all individuals from farming backgrounds, individuals from disadvantaged backgrounds did not experience any perceptible decrease in inequality within selection over the half century of the expansion of the educational system under consideration. This is a particularly remarkable result. Let us suppose that we dispose of a classification of the school population according to a (hypothetical) distance to a baccalaureate-level diploma, during the interwar period. This classification would be no more unequal than the one we would observe more than half a century later. The only difference being that the one established according to a (fictitious) distance to a higher education diploma would be in harmony with it. *Everything happens as if boys born into disadvantaged families (excluding farmers' children) saw their absolute positions improve along with the expansion of baccalaureate-level diplomas, while their relative position in the selection process results remained unchanged.* Moreover, their situation regarding access to the various groups of the boys population with the best educational opportunity (not including the top 20%) tended to worsen (Figure 2).

In contrast, we can appreciate the potential for change in the relative situation of children from disadvantaged social background knowing that between the first and the last birth cohort, the rate of access to secondary education of sons of manual workers varied from less than 20% to more than 90%,[17] and their rate of access to a high school diploma varied from about 14% to 56% (Table 2).

The stability of inequality within selection for access to education level L_{IV}, and even the deterioration of the intrinsic results of the selection process beyond a certain point of the opportunity distribution, mainly contradict the belief in intrinsic democratization (Thesis B: socioeconomic and institutional effects). Conversely, the decrease in inequality within selection for access to level L_{III} of higher education, down to a level equivalent to that of access at education level L_{IV}, mainly contradicts the belief in uniform democratization (Thesis A: social stratification effects). Moreover, we note that Theses A and B are not in contradiction in the case of socioeconomic evolutions involving changes in social stratification, so that the latter changes could engender a movement of intrinsic or qualitative democratization, as maintained by Thesis B. In other words, changes in the very framework in which Thesis A is usually situated – that of a stable social stratification system – should make the case for the validity of B. We observed the effects of these evolutions on democratization for access to higher education, but we have no reason to think that they have not also affected inequality within selection for access to other levels of education, especially to educational level L_{IV} (baccalaureate level); in fact, quite the contrary, so that we find neither of these theses satisfactory. None of them put educational policies into

question, Thesis B even supposes that these policies are favorable to intrinsic democratization. Our results do not even corroborate the idea of failure of educational policies in the face of the effects of social stratification but substantiate that of their counter-productive character.

In summary, let us assume that the evolution of the intrinsic results of the generative mechanisms of selection can be attributed to two major contextual or structural sets, economic and social factors, on the one hand, and educational factors, on the other hand. Then, the positive role attributable to the evolutions marked by the first set of factors on the relative educational opportunity of sons from disadvantaged backgrounds leads us to attribute a negative, counter-productive, role to the evolutions marked by the second set of factors, to explain the resulting status quo, and even increase, in the intrinsic inequality within the selection process.

Therefore, our results allow us to maintain Thesis C of "contradictory democratization", where the negative effects of school factors oppose the equalizing effects of socioeconomic factors on intrinsic educational opportunity.

Synthesis and concluding remarks

Understanding the observed differences in terms of inequality of opportunity of access to a specific good, between two populations or between two periods of time, depends on being able to grasp the intrinsic changes that affect the opportunity distribution underlying these differences. In this respect, it is important to keep to a reference frame that retains a stable meaning with regard to the results of social processes of selection, when overall access to the good at stake varies. The method used here offers a solution to this issue of measuring inequality within the selection process. Therefore, while the methods that were developed up to now to evaluate educational democratization processes generally aimed at assessing variations in the structure of social opportunities, the measurement of inequality within the selection process $\tilde{a}_g$ aims at supporting analyses of intrinsic changes in the effect of the microsocial processes of selection. Moreover, $\tilde{a}_g$ allows a diagnosis to be made at the various nominal levels. We applied this method to the analysis of the evolution of inequality within the selection process over the long term in France. This led us to presume a contradictory evolution of the selective social processes that accompanied educational expansion.

Independent of the fate of girls and all individuals from farm backgrounds who encounter changes that do not reflect, in a general way, the specific effects of educational policies, we observed that, when it occurred, a drop in inequality within selection – in the birth cohort 1940–1949 acceding higher education – was correlative with post-war large-scale socioeconomic changes and institutional transformations that led to the functional continuity of schooling from primary to secondary, and from secondary to higher education. These variations of the selection process reflect first and foremost changes in situational factors that affected the structure of the decision process on the part of individuals from various social subgroups. As a consequence, inequality within selection for access to higher education levels tended to converge towards inequality within selection for access to level L_{IV} (baccalaureate level). Nevertheless, this level has remained very stable over the 20th century, and, in the main, intrinsic inequality within the selection process tended to increase.

These major results led us to assume that the equalizing effects of economic growth and social changes, and the correlative increase in families' educational investment, hide a worsening of the school's effects on intrinsic democratization and, correlatively, to question the various theses put forward with regard to educational democratization. They allow clarification of the relationship between the thesis accrediting the development of a more meritocratic and egalitarian society and those, developed in parallel, certifying an essential maintenance of intrinsic forms of inequality. However, these general theses are mistaken about the role played by educational policies, either because they take institutional changes to be neutral or because they take them to further overall intrinsic democratization. We were therefore led to invalidate these two theses and develop the alternative thesis of "contradictory democratization". Our hypothesis is that economic and social changes must in fact have reduced inequality within the selection process for access to a baccalaureate-level diploma. These evolutions have thus tended to counterbalance, and then to obscure, the negative effects of educational policies on the relative achievement of students from disadvantaged backgrounds. The stability of inequality within the selection process for access to a baccalaureate-level diploma and, for those below the top 20% of the boys population, the increase of intrinsic inequality within the selection process appear to be the effect of these contradictory evolutions. In other words, school changes did not, in general terms, allow the potential provided by the massive expansion of demand for education during the period under study to be translated into an increase in equality of opportunity within the selection process.

In order to offer some explanation of such detrimental results of educational policies, we propose the following interpretation. Before school expansion, the prevalent system was one of "sponsored mobility" where the selection process was controlled by the established elites who distinguished their future peers at an early stage and trained them with this aim in view (Turner, 1960). Formal education relied on belief in the intrinsic value of education but, apart from sponsored mobility processes, social statuses' allocation remained, on the whole, socially predetermined. Socioeconomic development enhanced the various social groups' investment in secondary and higher education and, correlatively, the general integration of the educational system. These evolutions in educational choices mark the transition from a socially stratified system towards a more integrated one, permitting formal education to contribute to the substitution of "ascribed status" by "achieved status" within the social selection process, substantiating in this respect the modernization thesis. One consequence was a reduction in inequality within the selection process for access to higher education, marking a socially more egalitarian recruitment of all the future social elites.

In the resulting system of "contest mobility", school has a central role in the process of social status allocation. This explains the importance of equality of opportunity issues for sociology of education and schooling policies. However, school's primary mission of intellectual and cultural education has been reduced and altered. Responsibility for selection is mostly taken on by school but delayed as long as possible so as to give individuals the best opportunity of showing they can succeed on the basis of qualities which are not specifically academic ones. Education is not seen as having intrinsic value anymore, and its practical interest is valued, the primary objective being to keep all individuals in what is interpreted as a "competition" as long as possible. In this way, educational policies have conflated the democratization and the massification of school, and misunderstood its pedagogical mission.[18] As a result, the length of general education is extended, but intellectual or

cultural forms of education are now partly taken charge of outside school, by various processes which are socially biased: complementary and private education, the internet, extra-curricular activities, the notion of life-long learning, and so forth. This paradoxical development of the relative roles of selection and instruction of school and society constitutes, we assume, the major factor of the regression of the impact of school's factors in equalizing the educational selection process. The reason is that the school's fundamental mission is not to select, and that of market-oriented processes is not to intellectually and culturally educate. Disadvantaged groups always lose out in the end, since they have no true access to high-quality education.

Notes

1. Margins insensitivity, in a broad sense, means that the intensity of inequality evaluated by the index at stake keeps its significance whatever the margins' values of the contingency table are. One condition is that, in each context defined by the contingency table's margins, the same magnitude of inequality may be observed. The quality of margins insensitivity must therefore be distinguished from the precise aspect of inequality the index measures. See Blackburn and Marsh (1991), Ringen (2006), and Bulle (2016) on this subject.
2. The logarithm of the n_{ijk} total headcount of children from social background i, with educational destination j in the cohort k is broken down in linear form: $\ln(nijk) = \lambda + \lambda i + \lambda j + \lambda k + \lambda ij + \lambda ik + \lambda jk + \lambda ijk$ (classic breakdown of the variance analysis).
3. The odds is the probability of an event occurring divided by the probability of the event not occurring – for example, gaining access to G divided by being excluded from G: $p_1/(1 - p_1)$. An odds ratio is the odds of a particular outcome in one group divided by the odds for the same outcome in the other group. If p_1 is the probability of the outcome in Group 1, and p_2 is the probability of the outcome in Group 2, we have: odds ratio $= \frac{p1/(1-p1)}{p2/(1-p2)}$.
4. More precisely, opportunity of access to G is expressed as the percentile ranks of a fictitious "distance" to G. We note that opportunity of access diminishes with the rise of the distance to G, so that the relationship is negative. For instance, when we pass from the 25th percentile rank to the 65th percentile rank, we pass from a distance superior to 25% of other distances to G (meaning that 25% of the population has more opportunity) to a distance superior to 65% (meaning that 65% of the population has more opportunity).
5. Evoked here are hypotheses supported by interpretations of observable trends that are still in competition. More specific hypotheses, often linked to particular measurements detecting differential changes according to levels of education and the expansion of educational systems, cannot, for the sake of brevity, be evoked here. On this subject, see, for example, Shavit and Blossfeld (1993, pp. 6–10).
6. Blau and Duncan's (1967) analyses were based on data gathered from a Bureau of Census (1962) national panel of 20,000 individuals. One of the authors' main findings was that educational attainment had the strongest direct effect on occupational status, and that social origins had a strong influence on occupational status, but principally through educational attainment. They interpreted these findings by involving increasingly objective evaluation criteria, replacing the particularistic criteria of the different social groups. As a result, a person's achieved status, what he has achieved according to certain objective criteria, was supposed to become more important than his ascribed status, "what he was" in the sense of the family he comes from. This did not mean that family background no longer influenced careers but implied that a higher social status could not be inherited directly but had to be transmitted through socially controlled educational attainment.
7. As Bulle (2016, pp. 90–98) demonstrates, classical indices of inequality, such as odds ratios used in log-linear modeling, are sensitive to $\tilde{a}_g$ and to margins variations. Diagnoses of inequality variation may thus be convergent in case of $\tilde{a}_g$ variation and may not be in case of margins variation. If education is considered as a positional good, the diagnoses may come closer because

discrepancies between $\bar{a}_g$ and, for instance, odds ratios, only involve the variation of the distribution of social subgroups within the population.

8. We thank the Maurice Halbwachs Center for passing the data files on to us.

9. We grouped the 1910–1919 and 1920–1929 decades together because of the lack of certain variables in the 1970 FQP survey that does not permit us to distinguish all the educational levels L_V to L_{II}.

10. Note that the birth decade 1970–1979 is based on the 2003 survey only. The sample includes 1,288 boys and 1,123 girls from manual-worker families born between 1970 and 1979.

11. Main relationships with, for instance, EGP (Erikson Goldthorpe Portocarero) class schema are specified in Erikson, Goldthorpe, and Portocarero (1979, p. 420). We note that minor changes have been introduced in 1982 regarding subgroups of this classification which have been taken into account (see, e.g., Desrosières & Thévenot, 2002).

12. The various corresponding contingency tables – concerning the same 10-year birth cohort – from one survey to another, have been aggregated.

13. If we include the children of land-owning farmers we observe, as anticipated, a slight decrease of inequality within the selection process for access to educational L_{IV} and L_{III} following World War II.

14. The development of the access rate to the baccalaureate, for instance, can be compared, as Cherkaoui (1982, pp. 39–41) shows, to the diffusion of a cultural good, which can be modeled by a logistic function that would describe the endogenous rhythm of diffusion over time, the maximum speed being situated in the mid-1960s.

15.. These boys entered secondary education in the 1950s, and higher education before the end of the 1960s. The respective rates of access to a L_{IV} level of education and to a L_{III} (higher education diploma) level of education of boys not from farming backgrounds shifted between birth cohorts 1930–1939 and 1940–1949 from 19% to 27% and from 9% to 15% (Tables 2 and 3). These evolutions were part of the first phase of expansion of general baccalaureates (Figure 1).

16. These reforms were effective as from the end of the 1960s with the generalization of *Collèges d'Enseignement Secondaires* (CES) (i.e., junior high schools) and the creation of the beginning of a common core in the *collèges*. The complete elimination of streams in the *collèges* did not take place until the beginning of the 1990s.

17. To show that, with the integration of the educational system, the change in attitudes towards schooling has, in all likelihood, had a positive influence on the equalization of opportunity within selection for access to general (i.e., academic) education, one can refer, for example, to the large survey conducted in 1957, before the cancellation of the exam of entry to secondary education which selected students supposed to prepare an academic type of baccalaureate. This survey showed that about half of the pupils had the level to pass the exam but that almost half of them were not even candidates (Piéron & Reuchlin, 1958, p. 55).

18. On this subject (which cannot be discussed here) and for further analyses and references, see Bulle (2017, 2019).

Disclosure statement

No potential conflict of interest was reported by the author.

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Appendix 1. Defining an index of inequality within the selection process

As specified in Bulle (2016), inequality of access to a discrete good G can be ascribed to:

(1) Net results of the selection process in a broad sense. This concerns the effects of all of the factors influencing individuals' opportunities of access to G and defining a fictitious rank of precedence for access to G, but taking no account of individuals' actual access.
(2) Diffusion of G in society, that is, the overall fraction of the population accessing G.

Inequality with respect to (1) is inequality within the selection process, defined as a measure permitting comparison of the results of the selection process for access to G in a reference frame independent of the variation of overall access to G. The access of individuals from different subgroups Ci to a discrete good G can be interpreted as stemming from a virtual ranking of individuals from the whole population, as well as a function of the available quantity of G. This ranking permits one to refer to a fixed reference frame of relative opportunity. Inequality of subgroups Ci regarding such a reference frame represents what is defined as "inequality within the selection process".

More precisely, the results of the selection process could be apprehended directly if we could rank all the individuals of the population according to their relative opportunity of access to G – as if the results of the selection process could be represented by a queue, their effective access then only depending on the opening up of access to G. Suppose that:

(1) On the basis of such ranking, we divide our population into n groups of an equal size ordered according to an increasing "distance" to G (if $n = 10$, we would have the 10% with the best opportunity of access, then the following 10%, for any n we would have the first $\frac{100}{n}$%, the following $\frac{100}{n}$%, etc.).
(2) We measure the proportion of individuals belonging to each C_i social category which is present in each small group constituted, and the proportion (complementary to 1 of the preceding proportion) of individuals that do not belong to C_i, that is, those who belong to $\overline{Ci}$, the complementary set of C_i in the population.

Assuming that the population is sufficiently large and the opportunity strata sufficiently narrow, the distribution of the individuals belonging to C_i in the n small groups could be characterized by a continuous curve – the virtual limit of the histogram that has been set up, defined on the interval [0,1] (Y axis in Figure A1) – as could the distribution of the individuals coming out of $\overline{Ci}$. The functions represented by the obtained curves are joint density functions $\tilde{f}(x,Ci)$. These functions depend both on the discrete variable indicating that individuals belong to category C_i or $\overline{Ci}$ and on the continuous variable x defined on [0,1] (X axis in Figure A1), representing the distribution of relative opportunity of access to G – for example, $x = 0.25$ indicates the cutting point in our ordered population separating the 25% of individuals with the greatest opportunity of access to G from the rest of the population. The measure of inequality within selection is constructed on the basis of the definition of such a continuous opportunity distribution.

$C+g$ is defined as the "disadvantaged subgroup" – that is, the set of subgroups C_i where individuals have chances of access to G that are lower than the average. A virtual opportunity distribution of individuals from C_g^+ is constructed, based on the assumption of linearity of the opportunity curve described previously: This virtual distribution is supposed continuous and linear on the segment of [0,1] where these chances of access are not null and inferior to 100%. Two cases are distinguished in Figure A1: This segment is [0,1] in Case 1, it represents a subsegment of [0,1] in Case 2. This virtual distribution is such that knowing the overall access rate to G, this opportunity distribution could underlie the observed access to G of individuals from C_g^+.

The inequality coefficient $\tilde{a}_g$ is the slope of the straight line segment characterizing the opportunity distribution defined. Bulle (2016) shows that the coefficient $\tilde{a}_g$ represents an overall measure of inequality within the selection process and is insensitive to margins (x_j, the overall
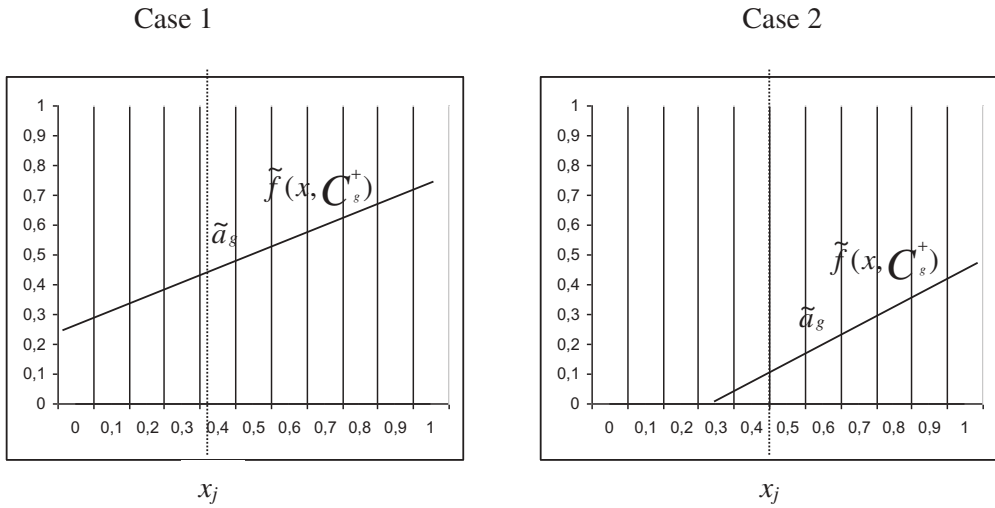
Case 1   Case 2

Figure A1. Virtual opportunity distributions.

access rate to G and m_g, the fraction of the whole population in C_g^+). In the following, r_g represents the access rate to G of individuals from C_g^+

Practical guide for the calculation of $\tilde{a}_g$ (according to Bulle 2016, pp. 103–104)

1 – Calculate the access rates r_i to the good G of the various social subgroups $C_{i.}$

2 – $\cup C_i = C_g^+$ is defined as the set of subgroups C_i where individuals have opportunity of access to G r_i that is lower than the average x_j. The value m_g is defined as the fraction of the population in social subgroup C_g^+, r_g as the access rate to G of individuals from C_g^+.

Calculate $a_g = \frac{2 \times m_g \times (x_j - r_g)}{(1 - x_j) \times x_j}$

Case 1 General case (case 1, Figure A1).

$\frac{a_g}{2} \leq m_g \leq 1 - \frac{a_g}{2}$ then $\tilde{a}_g = a_g = \frac{2 \times m_g \times (x_j - r_g)}{(1 - x_j) \times x_j}$

Case 2 $\tilde{d}(x, C_g^+)$ intersects the basis and not the top of the square where $\tilde{f}(x, C_g^+)$ is traced:

$m_g < \inf\left(\frac{a_g}{2} 1 - \frac{a_g}{2}\right)$, then $\tilde{a}_g = 2m_g \left[\frac{1 - \sqrt{r_g}}{1 - x_j}\right]^2$

Case 3 $\tilde{d}(x, C_g^+)$ intersects the top and not the basis of the square where $\tilde{f}(x, C_g^+)$ is traced:

$m_g > \sup\left(\frac{a_g}{2} 1 - \frac{a_g}{2}\right)$, then $\tilde{a}_g = 2 \left[\frac{\sqrt{1 - m_g} - \sqrt{1 - x_j - m_g + r_g m_g}}{x_j}\right]^2$

Case 4 $\tilde{d}(x, C_g^+)$ intersects the basis and the top of the square where $\tilde{f}(x, C_g^+)$ is traced:

$1 - \frac{a_g}{2} < m_g < \frac{a_g}{2}$ then $\tilde{a}_g = \frac{1}{2} \left[\frac{1}{\sqrt{r_g m_g} + \sqrt{1 - x_j - m_g + r_g m_g}}\right]^2$