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How do restrictive zoning and parental choices impact social diversity in schools? A methodological contribution to the decomposition of segregation indices applied to France

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Abstract

This paper provides a new method for decomposing segregation indices depending on two distinct set of unities. This method is applied to analyse how restrictive zoning and parental school choices impact social diversity in French middle schools. Using an exhaustive geolocalized dataset on three urban areas, segregation indices at the school level are decomposed into contributions of residential segregation and of circumvention. According to the results, for the three analysed urban areas, school choice accounts for one half of the social segregation across middle schools in Paris, and more than one third in the urban areas of Bordeaux and Clermont-Ferrand. This mostly stems from the fact that the social mix in "left behind" public schools is reduced as the parents who opt out of their neighborhood school for a private one are often the most advantaged ones locally.

Keywords. Social diversity, school choice, segregation indices, Entropy Index.
JEL Classification: I20, I24

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Introduction

Social segregation in schools has become an important issue in the French public debate. Social segregation among schools is accused of reducing social cohesion and being at least partly responsible for social inequities on education. In all countries, students with disadvantaged socioeconomic status usually have lower academic outcomes than students from more advantaged families, as they benefit from lower social, cultural and financial resources to succeed in schools. Attending a school that concentrates a large proportion of students from a disadvantaged background may constitute an additional obstacle for learning. For instance, such schools may struggle to attract better skilled teachers, and usually get higher levels of teacher turnover and supply teachers (Botton and Miletto [2018]) than more advantaged schools. This effect may be amplified if being enrolled with many low achievers has a negative impact on performance. Social and academic segregation may thus widen the educational gap between disadvantaged and advantaged students. Even if the literature on peer effects yield mixed results, social segregation is often found to be a threat for educational equity (Monso et al. [2019]). In addition, in the presence of a non-linearity in peer effects at school, the overall performance of the school system may also deteriorate. For instance, if good performers do not benefit as much from good peers (see for instance Abdulkadiroğlu et al. [2014], Lavy et al. [2012]) as low performers suffer from having bad peers, the aggregate effect of greater segregation would be negative.

Measuring the level of school segregation, and its complex links with urban segregation and school choice programs is thus crucial for designing policies aiming at improving both equity and quality in education - and this study provides new empirical tools in this objective. Specifically, it extends the type of decomposition that can be made with a common measure of segregation, the mutual information index (Frankel and Volij [2011]). This index provides a measure of the evenness of the social mix across schools. It can be decomposed to assess, for one thing, the relative contributions of public and private schools to the general level of school segregation. As we demonstrate here, this decomposition property may also be exploited in a setting where individuals (here students) are distributed across two distinct but overlapping sets of entities (in this case, either schools or residential neighborhoods). This two-side decomposition is used to quantify the relative contributions of residential segregation and selective choices made by families (to public or private schools) to overall school segregation.

This study provides a new empirical contribution on the debate regarding how school assignment rules, and specifically whether providing more freedom to families for choosing the school where to enroll their children, may alter the social composition in schools. Despite a large body of literature, this question is still unanswered. On one hand, school assignment based strictly on geographic catchment areas may lead to high levels of school segregation. The social composition of a school will directly reflect the social mix of its neighborhood. In urban areas where housing segregation is strong, residence-based allocation of students to schools may result in high social segregation. In addition, with strict neighborhood schooling housing segregation may be exacerbated as families include the quality of the schools in their choice of residence (Epple and Romano [1998]). As housing prices is expected to be higher in the vicinity of the best schools (see [Black, 1999] and for France [Fack and Grenet, 2010]), only well-off families may afford to locate in proximity to the best schools, while disadvantaged students may be stuck to low performing schools. This calls for policy aiming at breaking the link between residential location and access to public schools or by encouraging the development of private schools.

However, as emphasized by Musset [2012], most of the studies on the impact of an increased parental choice on segregation generally conclude that school choice options tend to deteriorate rather than improve the social mix in schools. For instance, Söderström and Uusitalo [2010] observe that the large scale reform that occurred in Sweden in 2000 lead to an increased social and ethnic segregation among schools, while the objective was on the opposite to minimize the effects of residential segregation by allowing access to the most prestigious schools for all pupils, without any constraint of residence area as was the case before. In school systems that promote

extensive school choice policies, it is usually the most affluent families who take advantage of the options provided by school choice. This may be because they have an easier access to the relevant information concerning school quality than other families, are able to pay additional costs for these schools (for instance fees for private school or commuting costs). Their preferences may also be more oriented towards high-achieving schools (see Fack and Grenet [2016] for an analysis on Parisian high schools). Accordingly, parents who are the most dedicated to school choice are often from high- or middle- class backgrounds. For instance, using data from French children entering sixth grade in 2007, Thaurel-Richard and Murat [2013] observe that advantaged families have a much higher propensity to opt out from the assigned public schools and especially to enroll their children in a private school. In another study, Fack and Grenet [2012] observe that the French policy implemented in 2007 with the objective of "relaxing" the school zoning yielded mixed results. Low income families, in principle the main target of the policy, have not become more likely to opt out from the assigned schools, while the policy increased the circumvention of some schools in disadvantaged areas and thus the concentration of disadvantaged students in these schools. Eventually, as the most popular schools are often oversubscribed and cannot admit all applicants, they may be tempted to "cream skim" students based on ability or even status. Selecting the brightest kids is the easiest way of maintaining a school's good reputation. Analysis from Germany (Riedel et al. [2010]), the United-Kingdom (Allen [2007], Johnston et al. [2006]) or Denmark (Rangvid [2007]) suggest that in many cases, enhanced school choices tend to increase school segregation relative to residential segregation.

School segregation, and its relation with residential segregation, is however expected to depend on the local context. Specifically, the spatial segregation that prevails locally, the type of school options that are provided, the way they are regulated (notably through the funding of schools), which parents actually resort to choice - and how responsive they are to school quality, are characteristics that may alter the actual sorting of students across schools. In the same way as Urquiola [2005] regarding the consequences of school competition on productivity, a comprehensive analysis on the consequence of school choice on social segregation among schools requires to look at three distinct sub-populations. Those who have access to distinct (and potentially better) schools than the one they would have been enrolled at in the absence of choice, those who are "left behind" in the less attractive schools, and finally students who would attend the best schools even in the absence of school choice options.

Our research is also in line with a large body of French qualitative and quantitative literature that stresses the role of school choice, which contributes to reduce the social mix in schools (see for example Oberti and Savina [2019], van Zanten [2009]). By using data on school zoning boundaries, it allows to quantify the role of school choice and residential segregation. Besides, separating the contribution of residential segregation from selective choice behavior requires accurate data, both on the residential address of pupils and on schools. In this paper, we use an exhaustive database of middle school pupils across three French urban areas (Bordeaux, Clermont-Ferrand and Paris) for which we know both the exact outlines of school zones and the addresses of the pupils in 2015. This makes it possible to identify for each student the school they would be assigned to if they respected the school zoning, but also to detect cases where this assigned school is circumvented. We can then compare the level of school segregation that would be observed if all pupils were enrolled in their assigned local public school, to the level of school segregation actually observed in middle schools. The first indicator reflects the share of school segregation that results from urban segregation, while the gap between the two measures makes it possible to assess the extent to which families' choices to opt out of the assigned public school aggravates or, on the contrary, leads to the resorption of a part of this residential segregation. Since opting out of the local public school implies attending either a private school or a public school different from the one initially assigned, one may then quantify the respective contributions of these two avoidance strategies.

These results are comparable to those obtained by simulations as proposed for instance in Allen [2007] in the case of the UK, or François [2002], Cadoret [2017] respectively for Paris and Clermont-Ferrand. However, the decomposition proposed here makes it possible to go further by measuring the impact on the social mix of avoided schools of "selective choice", meaning that families who opt out are usually the most well off and thus reduce the social mix in " left behind" schools from the "reallocation" effects, meaning that these students who opt out may contribute to increase the social mix in the schools they enroll.

The results confirm that, in the three French cities analysed here, the level of segregation observed at the middle school level reflects for a large part the level of urban segregation, consistently with the fact that the French enrollment system is closely related to residential locations. However, school choice options, and especially enrollment in private schools, contributes to reduce even further the social mix in middle schools. Circumvention of the assigned local public school accounts for 40 to 50 % of the level of segregation in middle schools. This result is, for the three cities studied here, essentially driven by avoidance towards private schooling. Our results allow us to go further in this decomposition. We show that this effect is explained by selective choice. In a neighborhood, students attending private schooling are often the most advantaged, and their defection further reduces the social mix in the avoided area. By contrast, the reallocation effects contributes only marginally to social segregation.

The next section presents the French system regarding the allocation of students to middle schools and its expected effects on segregation among schools. The second section proposes a decomposition of social segregation measured at the middle school level, between a part linked to urban segregation among school zones, and another resulting from the circumvention of the local public school. The results are presented in the third section, and the final one concludes.

1 Student allocations in schools in France

In France, the allocation of students to public middle schools is mainly based on the place of residence. All pupils are usually assigned one and only one public middle school, according to the definition of catchment areas. The school zoning is illustrated in the Figure 1, that represents an extract of the map of a city, with all public middle schools (in red) and the boundaries of their catchment areas. The school zoning for middle schools is defined by local authorities (*conseil départemental*). Its purpose is primarily to achieve allocation of pupils to schools depending on the latters' capacity. While in most cases, middle schools are rather centrally located within their catchment areas, it is not always the case and for some households in dense areas, the assigned middle school may not be the nearest school to their home.

Families who are not satisfied with the public school corresponding to their place of residence may request a waiver to enroll at another public school. Since 2007, the waiving possibilities were expanded and parents' motivations were given different degrees of priority. Being disabled, having special medical needs, being a grant holder are the most valued criteria. Seeking a specific curriculum (for instance, a rare second or third language such as Russian or Chinese) is among the less valued criteria. However it represents a quite large share of accepted waivers and even the majority in Paris (see Merle [2011]). Moreover, the zoning rule does not hold if the child was assigned to "special educational needs tracks" at the end of primary school. These tracks cater for children with significant learning difficulties or non-native speakers, and are offered only in certain schools (3% of children entering middle school in 2007, among which a half were not in the school corresponding to their school zone). Overall, 11% of children entering middle school in 2007 were enrolled in a public school distinct from the one assigned by the school zoning.[1]

[1]These figures are estimated using a large panel survey of French students entering sixth grade in 2007 – sixth grade corresponds to the first year of middle school. Parents were asked whether their child attended the school assigned by the school zoning, see Thaurel-Richard and Murat [2013] for details.

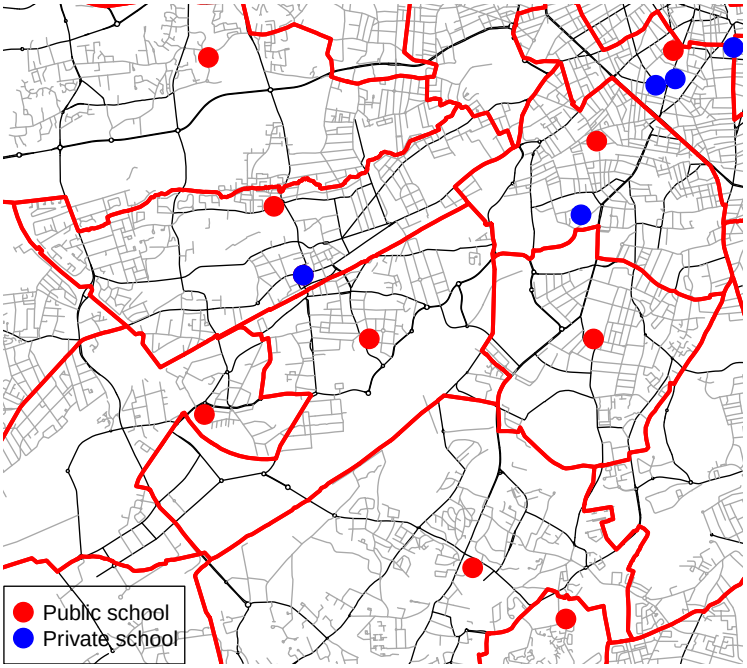

Figure 1: School zoning example in a suburban area

Lecture: The red lines correspond to school zoning boundaries, with each corresponding state school indicated in red and private schools in blue (a district may contain several or no private schools).

School choice is also provided to families through publicly subsidized private schools that enroll a large share of students. In 2007, 21% of French pupils entering middle school attended a private school (22% in 2015), a proportion stable since the 1980's. French private schools are mostly subsidized by public authorities: three quarters of the expenses of these schools are subsidized by the state (including the wages of teachers) or local authorities. The huge majority of middle schools are linked to the state through a "contrat d'association" (92% of middle schools, which gathered 99% of pupils in 2015). They commit to recruiting teachers with the same requirements as the public sector does, and are required to teach the same hourly volumes and curriculum as in the public sector. However, in contrast to public schools, private schools are not subject to restrictive zoning, have more autonomy in their management, are allowed to propose optional religious instruction classes, and can charge fees. Although the average fees are rather low by the standards of many other countries (thanks to the funding by the government), and are sometimes reduced for low-income families, they may still represent a financial obstacle. According to Secrétariat général de l'enseignement catholique [2019], in private Catholic middle schools (corresponding to around 95% of pupils in private schools having a contract), mean fees are around 800 euros per year. Moreover, private schools have greater control over intake than public schools, as they have freedom to enrol or not a student.[2]

Finally, because of historical reasons, most of French private middle or high schools are located in the neighborhoods close to city centers, as illustrated in the Figure 1 (private middle schools are represented by blue dots, and the denser city center is at the top right corner of

[2]In practice, parents should contact the school and the enrolment process may include several steps. Selection is usually based on past academic record, interviews with the headmaster for evaluating the motivation of the students. This comes with discriminatory practices, as illustrated for instance by Brodaty et al. [2014]. Letters from fictitious parents were sent to private school headteachers, parents having a foreign origin name were less often given a positive answer.

the map). These districts are usually the most affluent ones (see Champion and Tabard [1996], see also Givord et al. [2016] for an analysis on Marseille and Paris agglomerations). This may have impacted their composition, as many parents can be reluctant to send their children to a school located very far away from their home, which would imply a long commuting time. Such preferences have been highlighted regarding the choice of high schools in the Paris city: Fack and Grenet [2016] have shown that even though the academic level of the high school is taken into account by families, they usually prefer schools that are close to their home.

All in all, the intakes of French private schools are on average from more privileged background than those of public schools. This does not mean that private schools do not enroll students from disadvantaged families, though. In 2015, 20% of pupils attending private schools are from disadvantaged families (manual workers or unemployed) - but this proportion is more than twice higher in public schools (43%).

2 Decomposition of school segregation indices

2.1 Data and social background information

In France, the national administration of the Ministry of Education does not collect systematically data on the school map. We focused on three cities for which data on the school boundaries was easily available for statistical treatments : Bordeaux, Clermont-Ferrand and Paris. These three cities are different from each other regarding their total population and density. The inner city of Paris is nine times bigger (and four times denser) than Bordeaux and fifteen times bigger (six times denser) than Clermont-Ferrand. The income inequalities are also higher in Paris than in other French big cities.[3] A higher urban density and a higher level of economic disparities are expected to exacerbate residential segregation through housing market mechanisms (see Charlot et al. [2009]). However, this may make school choices easier, as the supply of alternative schools at close distance is often higher. These three towns thus provide quite distinctive urban contexts – which may help to identify any common patterns regarding the contribution of residential segregation and parental school choices to global segregation.

The data relies first on an exhaustive administrative source on middle and high school students, the *Scolarité* database, including their address geo-location. This database is combined with the accurate boundaries of school zoning. We can therefore identify, for each pupil, the public school he/she is assigned by school zoning, and the school where he/she is actually enrolled (and thus identify cases of school circumvention). We focus on middle school new entrants, usually aged 11 for those who have not previously repeated a grade. The analysis is conducted on the inner city of Paris, and on the broader urban areas of Clermont-Ferrand and Bordeaux, for year 2015.[4] We leave out of the analysis pupils who are attending "special educational needs" tracks, which are provided in a limited set of schools.[5] Among the 29,680 remaining pupils, 11% to 12% are avoiding their assigned public school in order to attend another public school (Table 1), and 20% to 30% are attending a private school. We refer to the first

[3]Regarding available income, the interdecile ratio is around 3,8 in Clermont-Ferrand, 4,5 in Bordeaux, and 6,3 in Paris (data from the French statistical national institute for year 2016).

[4]We only retain pupils who are both resident and enrolled in a school within each of the three urban areas considered, meaning that we leave aside some pupils who reside in the considered area but are schooled elsewhere, and conversely some pupils who are schooled there but reside outside. We choose to consider quite a large area around the cities of Clermont-Ferrand and Bordeaux, in order to minimize the number of pupils in such cases. However this perimeter must be restricted to dense areas where schooling alternatives actually exist. For these two areas, we therefore rely on the perimeter of "intercommunalities" (French *établissements publics de coopération intercommunale, EPCI).* Those are defined as a group of municipalities which gather together to share the charge of managing some services, like public transportation, collecting garbage or running water. However this choice was not possible nor relevant for Paris, for which we rely on the sole city area.

[5]Such tracks may enhance segregation, but we choose not to take them into account here, since they do not correspond to typical school circumvention strategies.

type as "Movers" to public schools (M^{pu}), to the second type as "Movers" to private schools (M^{pr}), and to the remaining pupils i.e. those who attend their assigned local school, as "Stayers" (S).

Table 1: Proportions of stayers and movers

		Proportion of		
	Number of students	Movers (private sector)	Movers (public sector)	Stayers
Bordeaux	7,927	0.21	0.11	0.68
Clermont-Ferrand	2,903	0.23	0.12	0.65
Paris	18,850	0.30	0.12	0.58

Source: MENJ-DEPP, Information System "Scolarité" and geolocalized student datafile. Authors' calculations.

The socioeconomic background of pupils is known at a fine level, through the occupation of both parents, using the French classification of occupations and social positions (*professions et catégories socioprofessionnelles*, PCS). While this detailed classification is directly available (32 categories), using it may lead to high levels of segregation in a purely mechanical way (as some categories may be totally absent of some schools). More generally, as shown by Carrington and Troske [1997], the segregation indexes can be severely biased upwards when some groups include a too small part of the population.[6] We therefore mainly rely on a four-category classification of parental occupations:[7] "Very advantaged" (including for example managers, teachers and professionals), "Advantaged" (including foremen, technicians), "Intermediate" (including employees) and "Disadvantaged" (manual workers or unemployed). This classification is traditionally used by the French Ministry of Education to study educational issues.

Table 2 presents the social composition of pupils in each urban area, depending on their type relative to school circumvention (M^{pr} / M^{pu} / S). Although the overall social composition differs between the three urban areas (with Paris having 50% of "Very advantaged" pupils, Bordeaux 36% and Clermont-Ferrand 29%), the pattern is generally the same regarding the relative social background of movers to the public and private sectors: for each urban area, the pupils attending private schools are more often "Very advantaged", although a few disadvantaged pupils are also concerned (more often so in Clermont-Ferrand and Bordeaux). The socioeconomic background of movers to another public school is similar (or even slightly lower) to that of the pupils who attend their local assigned school.[8]

2.2 Decomposing social segregation at school

Numerous measures have been proposed in the literature to measure segregation at school (see Frankel and Volij [2011]), as the association between schools and socioeconomic background. Here, we rely on a four-group classification, as using a binary index would entail too large a loss of information. Several segregation indices can be used in a multi-group version, among which the normalized entropy index H (see Reardon and Firebaugh [2002]).

[6] Carrington and Troske [1997] observe that, in a theoretical case where 100 pupils are randomly allocated to each school, and segregation is computed on a binary variable (for example having an immigrant background), the expected level of segregation is twice higher when the minority share is 5% compared to 30%. The intuition being that when the size of the minority group is very small, they by construction could not be represented in all schools – even in the absence of segregation patterns in the way students are enrolled in schools.

[7] Occupation of the "primary" parent, which by default is the father. The mother's occupation is taken into account when no information on the father's occupation is available.

[8] This result has been already documented by previous works from the French Ministry of Education. Thaurel-Richard and Murat [2013] observe that the average socioeconomic background of movers to another public school is lower than the average intake of public schools, but this is partly because they include pupils in "special educational needs tracks", whose come mostly from disadvantaged backgrounds. In Chausseron [2001], movers are over-represented both among children with teaching parents and children with unemployed parents.

Table 2: Social composition of students who opt out (movers) or stay in their assigned public schools (stayers)

Bordeaux	Movers (private sector)	Movers (public sector)	Stayers	All
Very advantaged	0.57	0.27	0.31	0.36
Advantaged	0.11	0.13	0.13	0.13
Intermediate	0.22	0.29	0.26	0.25
Disadvantaged	0.10	0.32	0.31	0.27

Clermont-Ferrand	Movers (private sector)	Movers (public sector)	Stayers	All
Very advantaged	0.41	0.24	0.26	0.29
Advantaged	0.15	0.09	0.13	0.13
Intermediate	0.28	0.24	0.24	0.25
Disadvantaged	0.16	0.43	0.37	0.33

Paris	Movers (private sector)	Movers (public sector)	Stayers	All
Very advantaged	0.73	0.39	0.40	0.50
Advantaged	0.07	0.08	0.08	0.08
Intermediate	0.16	0.27	0.26	0.23
Disadvantaged	0.04	0.26	0.26	0.19

Source: MENJ-DEPP, Information System "Scolarité" and geolocalized student datafile. Authors' calculations.

When considering a population of pupils that can be described by four social groups, and are enrolled in $k = 1 \dots K$ schools, the normalized entropy index is defined as:

$$\mathcal{H} = \sum_{k=1}^{K} \pi_k \frac{h(P) - h(p_k)}{h(P)} \tag{1}$$

where $P = (q_1, q_2, q_3, q_4)$ is the distribution of the four social origin types in the whole population, $p_k = (q_1^k, q_2^k, q_3^k, q_4^k)$ is the distribution of the four types in school k, $h(P) = \sum_{m=1}^{4} q_m ln(1/q_m)$ and π_k is the proportion of students who attend school k. This measure of the entropy can be seen as a measure of the diversity in the population, or the school. The normalized entropy index measures to which extent groups are evenly distributed among schools (see Massey and Denton [1988] for a classification of the different dimensions of segregation), or in this case whether the diversity observed at the level of the entire population is more or less reproduced at the scale of the schools.

In order to measure how school choice (in particular circumvention to private schools) affects school segregation, indices that verify an additive decomposition property should be favored. This property states that if we split the set of schools into two subsets, the segregation index measured for the set of all schools can be additively decomposed into a component opposing two sets of schools (for instance, private schools versus public schools), and two additional components that measure the level of school segregation within each of these sets respectively. The additive decomposition property states that:

$$I = I_{\text{Public vs. Private}} + \lambda_{\text{Public}} I_{\text{Public}} + \lambda_{\text{Private}} I_{\text{Private}} \tag{2}$$

where I is an additive decomposable segregation index measured using all schools, I_{Public} (respectively I_{Private}) the one using only public (respectively private) schools (and λs a weighting

scheme), and $I_{\text{Public vs. Private}}$ the segregation index comparing the distribution of social characteristics for all pupils in public schools with the one for all pupils in private schools. The normalized entropy index H satisfies such a property.

This decomposition is presented in Table 3. Whatever the urban area considered, the largest contribution to overall school segregation is due to the public sector (which is partly explained by the fact that this sector enrolled a largest share of students). It is smaller for Paris than in the two other regions, though: only 46% while it is 56% in Bordeaux and 64% in Clermont-Ferrand. The contribution of the public-private segmentation ranges from 20% in Clermont to 33% in Paris. The contribution of the social segmentation *within* the private sector is also substantial (around 17%-20%). This gives us a first picture of the contribution of private schools to social segregation among schools.

Table 3: Aggregate public sector- private sector decomposition of segregation

Bordeaux	Segregation index	% of school segregation
Total school segregation	0.099	100%
$I_{\text{Public vs. Private}}$	0.025	24.7%
$\lambda_{\text{Public}} I_{\text{Public}}$	0.056	55.8%
$\lambda_{\text{Private}} I_{\text{Private}}$	0.019	19.5%
Clermont-Ferrand	**Segregation index**	**% of school segregation**
Total school segregation	0.085	100%
$I_{\text{Public vs. Private}}$	0.017	19.9%
$\lambda_{\text{Public}} I_{\text{Public}}$	0.054	63.5%
$\lambda_{\text{Private}} I_{\text{Private}}$	0.014	16.6%
Paris	**Segregation index**	**% of school segregation**
Total school segregation	0.149	100%
$I_{\text{Public vs. Private}}$	0.050	33.3%
$\lambda_{\text{Public}} I_{\text{Public}}$	0.069	46.2%
$\lambda_{\text{Private}} I_{\text{Private}}$	0.031	20.5%

Source: MENJ-DEPP, Information System "Scolarité" and geolocalized student datafile. Authors' calculations.

However, this decomposition gives only a partial picture regarding the contribution of the different mechanisms driving school segregation. First, private schools are not the sole way to exert school choice. Within the public sector, parents can get a waiver to enroll their child in a school different from the one assigned by the school zoning. Second, the decomposition above does not separate school choice from residential segregation. French urban cities are usually highly segregated by income, and as school zoning is based on residential location, it induces school social segregation. Taking into account residential segregation has an impact on the measure of segregation within the public sector, since the recruitment of public schools depends directly on school zoning. Besides, it also has an impact on the measure of segregation within the private sector. Although private schools are not subject to the restrictive zoning, the distance criterion is important[9] as many parents prefer to choose a school located close to their home. The segmentation between private schools could mostly reflect residential segmentation among neighborhoods where private schools are implemented. On the other hand, the choice of private schools may be more socially differentiated within disadvantaged residential zones than in more

[9]Private schools are usually not boarding schools in France.

affluent neighborhoods, for instance if middle class families opt out to a private school in a more systemic way than less affluent families, while the local public schools enroll mostly pupils from disadvantaged families. It may be impossible with an aggregated measure to disentangle these two distinct mechanisms.

The proposed decomposition makes it possible to isolate the respective contributions of residential segregation and of the circumvention of the restrictive zoning to school segregation. The principle of the decomposition (which is detailed in Appendix A) relies on different partitions of segregation, first at the school level, and second at the residential level (according to the school zoning). It requires to know both the school where pupils should have been enrolled (according to the restrictive zoning) and the school they actually attend.

As a first step, only two types of pupils are considered: those who respect the zoning (and thus actually enroll in the public school that corresponds to their home location), indexed hereafter by S (as for stayers), and those who circumvent the school zoning, indexed by M (as for movers) irrespective of whether they attend a private school or a public school different from their assigned one. We may thus link H_{Sch}, the segregation index measured among schools (determined by pupils' actual enrollment) to H_Z, the segregation index measured among residential areas, as defined by the school zoning (determined by pupils' residential location), in the following way:

$$H_{Sch} = H_Z + \Delta H^M \tag{3}$$

where ΔH^M corresponds to the contribution of the circumvention of the school zoning to school segregation. It can be shown that ΔH^M is the sum of three terms (proofs in Appendix A):

$$\Delta H^M = \underbrace{\sum_z \lambda_z H_z^{S\ vs\ M}}_{(A)} \underbrace{- \sum_{sch} \lambda_{sch} H_{sch}^{S\ vs\ M}}_{(B)} \underbrace{+ \lambda^M (H_{Sch}^M - H_Z^M)}_{(C)} \tag{4}$$

The first term, $(A) = \sum_z \lambda_z H_z^{S\ vs\ M}$, reflects the local social segmentation between stayers and movers, within each zone z. $H_z^{S\ vs\ M}$ is the entropy index measured between stayers S and movers M when restricting the sample to zone z (the different λs denoting weights). The discrepancy between H_{Sch} and H_Z may therefore arise if within each school zone, the pupils who circumvent the local school differ in terms of social background from those who actually attend it. Not only does the social background of pupils matter, but also their residence area: the fact that an advantaged pupil opting out from its assigned school has lower detrimental effect on the school mix in this school if he or she leaves from an advantaged school zone rather than a disadvantaged one. This is illustrated on the Figure 2: Example 1 depicts the area A, composed equally of advantaged pupils (dark grey blocks) and disadvantaged pupils (light grey blocks). The social composition of movers is the same as that of stayers, so in this case $\mathcal{H}_A^{S\ vs\ M} = 0$. In Example 2, movers of zone B have the same social composition as movers of zone A, but they leave behind only disadvantaged pupils. This selective circumvention behaviour reduces the social mix and is expected to increase social segregation among schools: for area B, $\mathcal{H}_B^{S\ vs\ M} > 0$.

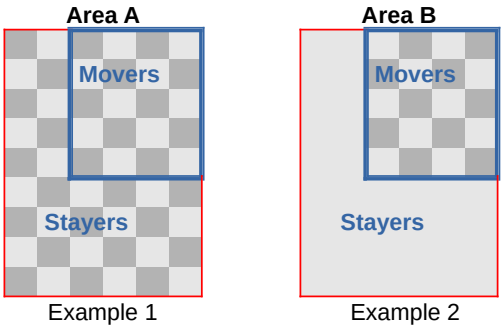

Figure 2: Illustration of equal vs selective opting out (residential area level)

Lecture: Dark and light grey blocks correspond to two types of students (for instance, advantaged and disadvantaged students). In both areas A and B, students who opt out from the assigned schools (movers) are equally mixed. However, while in the area A, the students left behind in the assigned schools (the stayers) are also of mixed types, in the area B they are only of light grey types.

Conversely, pupils circumventing their local school may increase the social diversity of the school they attend, if their social background differs from that of the pupils in the school joined. $(B) = -\sum_{sch} \lambda_{sch} H_{sch}^{S\ vs\ M}$ translates this diversity effect: $H_{sch}^{S\ vs\ M}$ is the entropy index measured between movers and stayers enrolled in school *sch*. For a given school *sch*, it increases when pupils enrolled in *sch* while theoretically assigned to another school (the movers) are socially different from pupils who are enrolled in this school because of the zoning (the stayers). Whereas the term (A) is mechanically positive, the term (B) is mechanically negative, and the two terms may offset each other. Terms (A) and (B) illustrate the *a priori* ambiguous contribution of school choice to segregation in schools, when school choice takes the form of circumventing the assigned local school. On the one hand, it may increase the level of segregation because in a neighborhood, pupils who opt out of the assigned school may differ from the ones who enroll in this school. On the other hand, school choice may decrease the segregation level if it allows children from disadvantaged or middle background to enroll in more privileged schools. This potential diversity effect is illustrated on Figure 3. Here again, movers have the same social composition in examples 1 and 2. Whereas their arrival in school 1 is neutral in terms of segregation ($H_1^{S\ vs\ M} = 0$), Example 2 presents a diversity effect when movers arrive in the very advantaged school 2 and bring some diversity: we therefore have $-H_2^{S\ vs\ M} < 0$. This situation corresponds for instance with the cases described by François [2002] where the fact that some families prefer to opt out from public school in advantaged neighbourhoods as for instance in the 6^{th} *arrondissement* of Paris allows some middle class families to enroll their children in these overall advantaged schools, resulting in an increase in the local mix in these schools.

The term $(C) = \lambda^M (H_{Sch}^M - H_Z^M)$ translates the idea that pupils circumventing their local school are eventually sorted or mixed into the schools they are actually enrolled in. H_{Sch}^M is the entropy index measured between movers, when considering their distribution among the

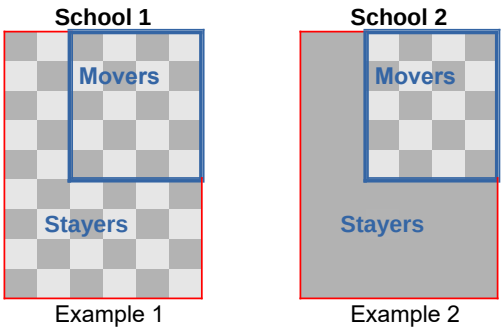

Figure 3: Illustration of reallocation (school level)

Lecture: Dark and light grey blocks correspond to two types of students (for instance, advantaged and disadvantaged students). Students who are enrolled in both schools 1 and 2 while they are assigned to another school by the school zoning (movers) are equally mixed. However, while in the school 1, the students assigned by the school zoning (stayers) are also equally mixed, in the school 2 the students assigned by the school zoning are only of dark grey type and movers thus help to increase the social mix in this school.

schools they eventually attend. It is mitigated by H_Z^M, the entropy index between movers measured among residential areas. For example, (C) may be negative if some pupils from a privileged background and others from a disadvantaged background who circumvent their respective assigned schools, eventually enroll in the same school. Such a case is illustrated in the Figure 4 that considers for the sake of simplicity only students opting out from their local school (movers). They come from two areas A and B that are socially distinct (area A is mainly composed of disadvantaged students, while area B is socially mixed). In the Example 1, movers from these two distinct areas are eventually enrolled in the same school, resulting in higher social diversity at the school level ($\lambda^M(\mathcal{H}_{Sch}^M - \mathcal{H}_Z^M) < 0$). Example 2 shows a case where school 1 enrolls only the disadvantaged pupils (either from areas A or B), while the school 2 enrolls mostly advantaged pupils. This "social specialization" of schools brings to an additional social stratification compared to the initial level of residential segregation among movers and we would therefore have $\lambda^M(\mathcal{H}_{Sch}^M - \mathcal{H}_Z^M) > 0$.

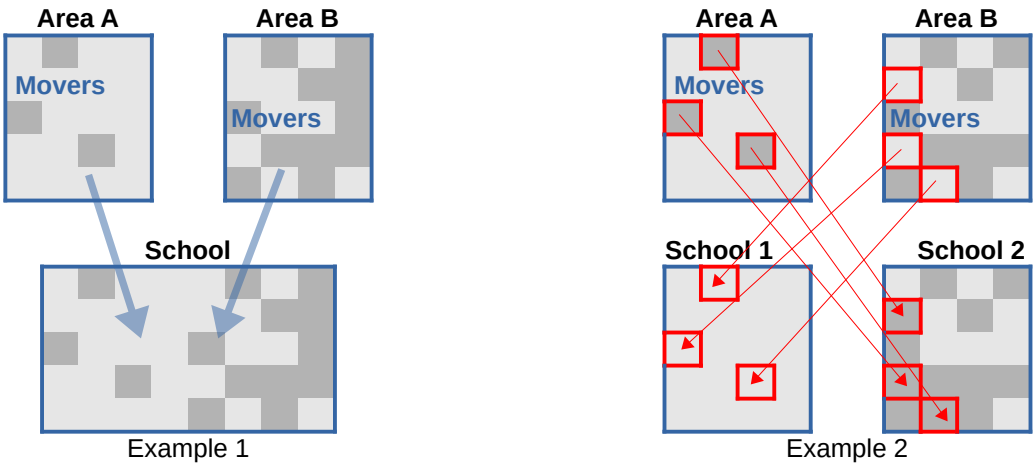

Figure 4: Illustration of increasing vs decreasing social mix amongst movers (from area to school level)

Lecture: Dark and light grey blocks correspond to two types of students (for instance, advantaged and disadvantaged students) - only movers are represented. In Example 1, all students are eventually mixed in one single school, while in Example 2, they are sorted in two distinct schools depending on their type.

2.3 Circumvention to private vs. public schools

We can further detail this decomposition, by comparing the component due to circumvention to private schooling, from circumvention to another public school. If we denote those who circumvent the zoning for a private school $PR = M^{PR}$ (movers to private school) and those who circumvent the zoning for a public school M^{PU} (movers to a public school), and finally $PU = M^{PU} + S$ all pupils attending a public school (whether it is their assigned one or not), it may then be shown that (see the proof in Appendix A):

$$\mathcal{H}_{Sch} = \mathcal{H}_Z + \Delta\mathcal{H}_{M^{PR}} + \Delta\mathcal{H}_{M^{PU}} \tag{5}$$

with :

$$\Delta\mathcal{H}_{M^{PR}} = \underbrace{\sum_z \lambda_z \mathcal{H}_z^{PR\ vs\ PU}}_{\text{1: selective opting out(=A)}} + \underbrace{\lambda^{PR}(\mathcal{H}_{Sch}^{PR} - \mathcal{H}_Z^{PR})}_{\text{2: reallocation effect (=C)}} \tag{6}$$

$$\Delta\mathcal{H}_{M^{PU}} = \underbrace{\sum_z \lambda_z \mathcal{H}_z^{M^{PU}\ vs\ S}}_{\text{1': selective opting out (=A)}} \underbrace{- \sum_{sch} \lambda_{sch} \mathcal{H}_{sch}^{M^{PU}\ vs\ S} + \lambda^{M^{PU}}(\mathcal{H}_{Sch}^{M^{PU}} - \mathcal{H}_Z^{M^{PU}})}_{\text{2': reallocation effect (=B+C)}} \tag{7}$$

The interpretation is the same as before, with (1) and (2) the counterparts for private schools of terms (A) and (C) of Equation 4; and (1') and (2') the counterparts for movers to public schools of (A) and (B)+(C) respectively.

Two remarks should be made. First, all pupils enrolled in private schools are by definition movers in our taxonomy (private schools do not belong to the public school zoning system), therefore movers do not mix with stayers when they enroll in private schools. This explains why for private schools, there is no counterpart of the second term (B) in the general decomposition 4: the only existing reallocation effect takes place *within* movers to private schools. For movers to public schools, we designate as "reallocation" effect the combination of the diversity effect (B) in the schools joined and of the "social specialization" effect (C) among movers to public schools.

Second, the first term is not computed in exactly the same way for circumvention to private and to alternative public schools in the decomposition proposed in 7. In this decomposition, we first consider pupils enrolled in private school separately from all others,[10] and then compare the impact of circumvention from assigned school *restricted to pupils enrolled in public school*. Thus, for the same residential zone z, for ΔH_{MPR} we single out pupils enrolled in a private school among all pupils living in this zone, while in ΔH_{MPU} we contrast pupils enrolled in an alternative school to resident pupils (once excluded the pupils enrolled in private school). Another option would have been to first single out pupils who circumvent to alternative public school, and then compare stayers with movers to a private school. The computation is expected to be order-dependant and thus to vary from our main specification. However, the main conclusions regarding the relative magnitude of the different components are maintained whatever option has been chosen.

3 Results

The detailed decomposition is performed in each of the three urban areas considered: Bordeaux, Clermont-Ferrand and Paris (Table 4). In all cases, school segregation partially reflects the residential segregation level - which is consistent with the fact that 80% of students are enrolled in public schools, and assigned to them depending most frequently on their home address. However, circumvention of the assigned public school contributes to school segregation in a non marginal way. This contribution is 39.2% for Bordeaux, 37.1% for Clermont-Ferrand and as much as 49.0% for Paris. In the latter case, segregation measured at the school zoning level is only around half as that measured among schools. The magnitude of the effects between the three urban areas cannot be directly compared, given the different perimeters considered (strict city boundaries for Paris, wider urban areas for Bordeaux and Clermont-Ferrand) and the population densities implied.

In all three districts, the contribution of circumvention strategies to school segregation is mostly due to the choice of private schools. Within this contribution of private schools, the most important contribution is the term measuring socially selective circumvention (term (1) in the decomposition (6)). *Within each catchment area of the public school*, the pupils who circumvent their assigned school to attend a private one have a social composition that is very different from that of pupils remaining in the public sector. Eventually, the students they "leave behind" are less socially diverse than in their residential area. This socially selective effect accounts for 31.2% in Bordeaux, 32.9% in Clermont-Ferrand and 39.8% in Paris.

In the three cities considered here, these locally segregative effects of private school attendance are not mitigated by a reallocation effect at the aggregated level. The reallocation effect measures the fact that, within private schools, students from diverse social background may be eventually mixed together (i.e. the term (2) of the decomposition (6)). Specifically, this term may be negative in principle if pupils who are enrolled in private education are less socially stratified according to the school they attend than according to their residential neighborhood.

[10] It should be noted that the global contribution of the private sector $\Delta\mathcal{H}_{MPR}$ is exactly equivalent to the term that would be obtained with simulation techniques, as mentioned before. The same holds for the contribution of school choice in public sector.

According to our data, in Bordeaux and Clermont-Ferrand, this contribution is very small and not significantly different from 0 at the 10% level. For those urban areas, social segmentation between private schools mostly corresponds with preexisting residential segregation among the pupils who circumvent to those private schools. In Paris there is a slight additional stratifying effect of private education (4.7%, significant at the 5% level). Far from allowing diversity *among private school pupils*, the private sector contributes to sort them even more between middle schools. The differences observed between the three cities in this respect may be due to various local policies regarding private education[11]. Because their recruitment is not constrained by the school zoning, private schools may adapt their teaching offer to specific needs, including pupils with learning difficulties or, on the contrary, high-achieving children (see Barthon and Monfroy [2006] for an analysis on the Lille city).

Table 4: Detailed decomposition of school segregation

	Bordeaux		**Clermont-Ferrand**		**Paris**	
		% of $\mathcal{H}_{Sch}$		**% of $\mathcal{H}_{Sch}$**		**% of $\mathcal{H}_{Sch}$**
School segregation ($\mathcal{H}_{Sch}$)	0.099 (0.0040)	100%	0.085 (0.0060)	100%	0.149 (0.0031)	100%
Residential segregation ($\mathcal{H}_Z$)	0.060 (0.0033)	60.8%	0.053 (0.0050)	62.9%	0.076 (0.0024)	51.0%
Contribution of all movers ($\mathcal{H}_{Sch} - \mathcal{H}_Z = \Delta\mathcal{H}_{M^{PR}} + \Delta\mathcal{H}_{M^{PU}}$)	0.039 *** (0.0031)	39.2%	0.031 *** (0.0054)	37.1%	0.073 *** (0.0025)	49.0%
Movers to private schools ($\Delta\mathcal{H}_{M^{PR}} = (1) + (2)$)	0.033 *** (0.0027)	33.3%	0.028 *** (0.0047)	33.2%	0.066 *** (0.0023)	44.5%
M^{PR} selective circumvention effect (1)	0.031 (0.0025)	31.2%	0.028 (0.0039)	32.9%	0.059 (0.0020)	39.8%
M^{PR} reallocation effect (2)	0.002 ^{ns} (0.0019)	2.2%	0.000 ^{ns} (0.0032)	0.4%	0.007 * (0.0015)	4.7%
Movers to public schools ($\Delta\mathcal{H}_{M^{PU}} = (1') + (2')$)	0.006 *** (0.0017)	5.9%	0.003 ^{ns} (0.0032)	3.9%	0.007 *** (0.0014)	4.5%
M^{PU} selective circumvention effect (1')	0.012 (0.0016)	11.9%	0.014 (0.0027)	16.9%	0.012 (0.0011)	7.9%
M^{PU} reallocation effect (2')	−0.006*** (0.0018)	-6.0%	−0.011*** (0.0032)	-13.0%	−0.005*** (0.0013)	-3.3%

Source: MENJ-DEPP, Information System "Scolarité" and geolocalized student datafile. Authors' calculations. Note: (.) p<0.1; (*) p<0.05; (**) p<0.01; (***) p<0.001; (ns) not significant. Standard errors are computed by bootstrap. Information on significance levels is irrelevant when the value can only be positive, and is not given in this case.

The circumvention to another public school (than the one assigned by the school zoning) contributes only slightly to increase segregation: the overall contribution is +5.9% for Bordeaux and +4.5% for Paris. For Clermont-Ferrand, it is not significantly different from 0. Again, this is mostly due to the socially selective circumvention effect (term (1') in the decomposition) that contributes to increase social segregation: it ranges from 7.9% in Paris to 16.9% in Clermont-Ferrand. It is almost cancelled out by a reallocation effect (term 2'), as the students who opt out of their assigned public school are eventually contributing to increase social diversity in the schools they attend. This may happen for instance if it is mainly middle-class families who tend to opt out from schools located in socially mixed neighborhoods, and enroll their children in public schools located in more advantaged areas. These middle-class children may "bring" a social diversity in schools that would otherwise enroll only high-income families.[12]

[11] One should also keep in mind that for Paris, the field of analysis could not be defined on the same basis than Bordeaux and Clermont-Ferrand, as mentioned above. This may also drive the differences between cities.

[12] A caveat should be made as in some cases, circumvention to another public school may be achieved by using a different address than the actual home address - which cannot be detected using administrative data.

4 Concluding remarks

The first contribution of this paper is to provide a detailed description of social segregation in middle schools in three French cities, characterized by quite different local conditions, Bordeaux, Clermond-Ferrand and Paris. The proposed decomposition allows us to illustrate the magnitude of the distinct components that may explain the social segregation prevailing among schools in these cities. The results suggest that at least half of the school segregation is due to initial residential segregation, conveyed by the strict school zoning. However, this segregation is aggravated by selective circumvention strategies. The social composition of students who opt out of the public school assigned by the school zoning is often distinct from that of students who stay in their local school. This results in a lower social mix in the public schools "left behind". This effect may be in theory offset by a higher social mix in the schools (either public or private) where these students eventually enroll at, but in practice this effect is at best marginal (and, in the case of Parisian private middle schools, contributes on the contrary to higher social sorting of students). All in all, the effect of circumvention to private schools accounts for 33% to 45% of the school segregation level.

These results provide descriptive evidence and not causal evaluation of the impact of school assignment rules. Using strict residence-based assignment to school is expected to exacerbate residential segregation. For instance, Fack and Grenet [2010] observe that the rather low elasticity of the housing price to school quality in the case of the city of Paris is explained by the large supply of private schools. Restricting these circumvention possibilities is expected to eventually increase residential segregation and thus may exacerbate school segregation. However, international examples suggest that school choice without regulation is expected to increase segregation (OCDE [2019]). In countries as diverse as Chile, New Zealand or Sweden that have introduced large scale policies aimed at providing parents with complete freedom to choose the school where they want to enroll their children, the final results are a higher sorting of students by ability, ethnic and social background (see for instance Hsieh and Urquiola [2006], Ladd and Fiske [2001]), without significant impact on the efficiency of schools. More balanced solutions may be considered. For instance, some educational systems promote school choice through educational vouchers - meaning a public funding of school expenses for students, whatever the school they choose to enroll. Educational vouchers targeted to low-income or disadvantaged students are expected to increase equity (Ladd [2002], Epple et al. [2017]) while on the contrary universal voucher systems are likely to increase the socioeconomic stratification of schools. For example, public and private voucher plans in the U.S. have been generally limited to children from poor families in order to offer them choices outside the local school. In the Netherlands, schools that enroll students from disadvantaged backgrounds receive more government financial support in order to reduce sorting. Admissions requirements, especially for over-subscribed schools, may also be strictly regulated. In some voucher programs (such as the Milwaukee program in the United States), schools with more applicants than available spots are required to choose a portion of students by lottery to assure fairness in selection procedures. Finally, in many places regulating school choice at the district or city level is now achieved by centralized matching algorithms (such as the so-called "Boston mechanism"). Including socioeconomic criteria in the procedure is proven to be an efficient way of increasing the social mix in schools, as shown in the case of Paris high schools by Fack and Grenet [2016]. However, in order to be fully efficient, this would require equality of treatment for public and private schools. For instance, in the Netherlands or in Belgium, public and private schools are equally funded by the government but also obliged to the same regulations, notably regarding admission procedures.

Some other policies may help to alleviate the impact of residential segregation on school segregation. Displacing or removing borders of the school map in selected places can help to create more socially diverse school zones. However, their implementation can be difficult due to local oppositions, or because families adapt their school choice behaviour, for instance by choosing more often private schools. In the context of the "Improving social mix in junior high

schools" plan since 2015, some French local authorities have launched experiments and work with researchers in order to determine conditions in which policies can improve social mix in schools. In the case of Paris, first results seem to indicate that some policies aiming at removing borders between two adjacent zones, and create two-school-zones, may improve social mix in the corresponding schools, when they go together with adaptations in the school recruitment procedures (Grenet and Souidi [2018]).[13]

On the methodological side, this paper proposes a new way of decomposing common segregation indices when two possibly distinct partitions of the population can be used. By singling out distinct components that contribute to segregation (selective avoidance vs reallocation effects), it provides a more accurate picture of the mechanisms underlying segregation. Such a decomposition can be used in different contexts that the one used here: for instance, it can be used in order to analyse the changes in residential segregation. In this case, one may examine the places of residence at two distinct dates. This may for instance help to measure whether residential mobility processes (analysing both mobility from or into disadvantaged vs privileged neighborhoods) reinforce broader segregation patterns.

[13]Moreover, educational policies can help to improve the image and educational offer of some schools, which contributes not only to their own attractiveness, but also to improving the image of the district where they are located.

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A Decomposition

For a set of R zones, we have Rx3 initial groups defined by a school zone and a status (circumventing to a state school /circumventing to a private school / enrollment in the assigned school). The principle of the segregation decomposition relies on the fact that we can reorder these partitions of Rx3 groups in two ways: the one depending on school zones, the other depending on actual school. We can thus define a segregation index measured when using the full partition, and decompose it in either residential units, or school units. Figure A illustrates these two options in a case with students who may opt out for another public school: pupils who circumvent zone A enroll in school B, and in zone B those who circumvent enroll in school C. Here we leave private schools aside for the sake of clarity, and there is no group of circumventing pupils from zone C, so overall there is a set of five groups. The measure of segregation corresponding to this full partition (here the five group partition) is not an object of interest in itself, but will be used to compare the measures of residential segregation and school segregation.

Figure 5: Illustration : from residential segregation to school segregation

Note: Each tile corresponds to a pupil, for example the advantaged ones in dark grey. The five subgroups (middle) can be divided into three sectors (above) or three colleges (bottom). The total segregation between the five subgroups can thus be linked, on the one hand, to segregation between sectors and, on the other hand, to segregation between colleges.

Let us now turn to a more general case. We denote by $\mathcal{H}_Z^T$ the entropy index calculated for the full partition of all entities corresponding to the interaction between type k (stayers S, movers to state school M^{PU}, movers to private school M^{PR}) and residential zones z. As already mentioned, this index that uses the two dimensions is used only for the sake of calculation (as it does not have direct interpretation in itself).

$$\mathcal{H}_Z^T = \sum_z \sum_{k \in (S,\ M^{PU},\ M^{PR})} \pi_z^k \frac{h(P) - h(P_z^k)}{h(P)}$$

where P is the distribution of pupils in the different socioeconomic groups in the whole population, P_z^k are the corresponding distributions in the zone z for pupils of type k, and π_z^k the proportions of these pupils in the whole population. Specifically, we have fif$\pi_z^k = \frac{\mathbf{N}[(k,z)]}{N_T}$ where $\mathbf{N}[(k,z)] = Card(i \text{ of type } k \text{ and in zone } z)$ and N_T the size of the total population. We can decompose this index $\mathcal{H}_Z^T$ in two different ways, first by focusing on zones:

$$\begin{aligned}
\mathcal{H}_Z^T =& \underbrace{\sum_z \pi_z \frac{h(P) - h(P_z)}{h(P)}}_{\mathcal{H}_Z} + \sum_z \frac{h(P_z)}{h(P)} \sum_{k \in (S,\ M^{PU},\ M^{PR})} \pi_z^k \frac{h(P_z) - h(P_z^k)}{h(P_z)} \\
=& \mathcal{H}_Z + \sum_z \frac{h(P_z)}{h(P)} \frac{N_z}{N_T} \underbrace{\frac{\mathbf{N}[(M^{PR}, z)]}{N_z} \frac{h(P_z) - h(P_z^{M^{PR}})}{h(P_z)} + \frac{\mathbf{N}[(M^{PU} \text{ or } S, z)]}{N_z} \frac{h(P_z) - h(P_z^{M^{Pu}+S})}{h(P_z)}}_{\mathcal{H}_z^{M^{Pr} vs (M^{Pu}+S)}} \\
&+ \sum_z \frac{\mathbf{N}[(M^{PU} \text{ or } S, z)]}{N_T} \frac{h(P_z^{M^{Pu}+S})}{h(P)} \underbrace{\frac{\mathbf{N}[(M^{PU}, z)]}{\mathbf{N}[(M^{PU} \text{ or } S, z)]} \frac{h(P_z^{M^{Pu}+S}) - h(P_z^{M^{Pu}})}{h(P_z^{M^{Pu}+S})} + \frac{\mathbf{N}[(S, z)]}{\mathbf{N}[(M^{PU} \text{ or } S, z)]} \frac{h(P_z^{M^{Pu}+S}) - h(P_z^S)}{h(P_z^{M^{Pu}+S})}}_{\mathcal{H}_{z,(M^{Pu}+S)}^{M^{Pu} vs S}} \\
=& \mathcal{H}_Z + \sum_z \left[\lambda_z^1 \mathcal{H}_z^{M^{Pr} vs (M^{Pu}+S)} + \lambda_z^2 \mathcal{H}_{z,(M^{Pu}+S)}^{M^{Pu} vs S} \right]
\end{aligned}$$

with $\mathcal{H}_Z$ the entropy index corresponding to residential segregation (considering all pupils of one residential areas), $\mathcal{H}_z^{M^{Pr} vs (M^{Pu}+S)}$ the entropy index restricting the sample to pupils living in residential area z, and comparing the distribution of social groups among pupils enrolled in private school with the one among pupils enrolled in public school, $\mathcal{H}_{z,(M^{Pu}+S)}^{M^{Pu} vs S}$ the entropy index restricting the sample to pupils living in residential area z *and* enrolled in public school, and comparing the distribution of social groups among pupils enrolled in the assigned public school with the one among pupils circumventing toward another public school. The terms λ_z^1 and λ_z^2 correspond to weights.[14]

By now decomposing this very same index $\mathcal{H}_Z^T$ by types k (instead of zones) we have also:

$$\begin{aligned}
\mathcal{H}_Z^T =& \underbrace{\sum_k \pi^k \frac{h(P) - h(P^k)}{h(P)}}_{\mathcal{H}^K} + \sum_k \frac{h(P^k)}{h(P)} \pi^k \underbrace{\sum_z \pi_{k,z}^k \frac{h(P^k) - h(P^k z)}{h(P^k)}}_{\mathcal{H}_Z^k} \\
=& \mathcal{H}^K + \sum_k \lambda^k \mathcal{H}_Z^k
\end{aligned}$$

with $\mathcal{H}^K$ denotes the entropy index considering a partition depending on the type (stayers, movers to public, movers to private school) only, and $\mathcal{H}_z^k$ the entropy index measuring residential segregation, when restricting the sample to one type k.

[14] We have $\lambda_z^1 = \frac{h(P_z)}{h(P)} \pi_z$ and $\lambda_z^2 = \frac{h(P_z^{M^{PU}+S})}{h(P)} \pi_z^{M^{PU}+S}$

We can also do the same type of decomposition by considering the full partition of all entities corresponding to the interaction between both type k and school s. When now considering entities based on type and enrollment school (instead of residential zoning), we have a similar decomposition:

$$\begin{aligned}\mathcal{H}^T_{Sch} =& \sum_s \sum_k \pi^k_s \frac{h(P) - h(P^k_s)}{h(P)} \\ =& \underbrace{\sum_s \pi_s \frac{h(P) - h(P_s)}{h(P)}}_{\mathcal{H}_{Sch}} + \sum_s \frac{h(P_s)}{h(P)} \sum_{k \in (S,\, M^{PU},\, M^{PR})} \pi^k_s \frac{h(P_s) - h(P^k_s)}{h(P_s)}\end{aligned}$$

It is useful to underline some simplifications. In private schools, all students are of type $k = M^{PR}$ and in public ones, they are either of type S or M^{PU}. Compared to the decomposition above, the second term of this decomposition is thus null. Using similar notation as above we therefore have:

$$\begin{aligned}\mathcal{H}^T_{Sch} =& \mathcal{H}_{Sch} + \sum_s \lambda^2_s \mathcal{H}^{M^{Pu} vsS}_{s,(M^{Pu}+S)} \\ =& \mathcal{H}^K + \sum_k \lambda_k \mathcal{H}^K_{Sch}\end{aligned}$$

the second line providing when considering only the partition by type of students. We thus have:

$$\begin{aligned}\mathcal{H}^K =& \mathcal{H}_Z + \sum_z \left[\lambda^1_z \mathcal{H}^{M^{Pr} vs(M^{Pu}+S)}_z + \lambda^2_z \mathcal{H}^{M^{Pu} vsS}_{z,(M^{Pu}+S)}\right] - \sum_k \lambda^k \mathcal{H}^K_Z \\ =& \mathcal{H}_{Sch} + \sum_s \lambda^2_s \mathcal{H}^{M^{Pu} vsS}_{s,(M^{Pu}+S)} - \sum_k \lambda^k \mathcal{H}^K_{Sch}\end{aligned}$$

Finally, we obtain:

$$\mathcal{H}_{Sch} = \mathcal{H}_Z + \underbrace{\sum_z \lambda^1_z H^z_{M^{Pr} vs(M^{Pu}+S)} + \lambda^{PR}[\mathcal{H}^{M^{Pr}}_{Sch} - \mathcal{H}^{M^{Pr}}_Z]}_{\Delta\mathcal{H}_{M^{Pr}}} + \underbrace{\sum_z \lambda^2_z \mathcal{H}^{M^{Pu} vsS}_{z,(M^{Pu}+S)} - \sum_s \lambda^2_s \mathcal{H}^{s,(M^{Pu}+S)}_{M^{Pu} vsS} + \lambda^{PU}[\mathcal{H}^{M^{Pu}}_{Sch} - \mathcal{H}^{M^{Pu}}_Z]}_{\Delta\mathcal{H}_{M^{Pu}}}$$

as by definition of the stayers (students enrolled in the school assigned by the zoning), $\mathcal{H}^S_{Sch} = \mathcal{H}^S_Z$ and denoting $\lambda^{PU} = \lambda^{M^{PU}}$ and $\lambda^{PR} = \lambda^{M^{PR}}$.

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