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## ► To cite this version:

Kévin Beaubrun-Diant, Tristan-Pierre Maury. Income Segregation and Social Housing in France. 2020. hal-02526776

**HAL Id: hal-02526776**

**<https://hal.science/hal-02526776>**

Preprint submitted on 31 Mar 2020

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# Income Segregation and Social Housing in France

Kevin Beaubrun-Diant\* and Tristan-Pierre Maury†

March 31, 2020

## Abstract

This article provides a geographical analysis of the contribution of social housing to income segregation in France from 1999 to 2015 at very detailed spatial scale. During this period, a law required some French municipalities (with more than 3500 inhabitants in large conurbations) to build more social housing to reduce segregation. Surprisingly, it appears that while home tenure (social vs private housing) segregation has been decreasing, income segregation has been rising. With segregation decomposition techniques, we provide evidence that this is a side-effect of the legal framework: decreasing income segregation in the geographical scope of the law but a flight effect of middle and upper class households out of it.

## A Introduction

Socioeconomic segregation refers to the separation of populations into different districts or neighborhoods according to their socioeconomic characteristics (income, occupation classification, employment). The geographical clustering of households or individuals with common features is a well-known phenomenon that has been documented in many countries. A high level of segregation means that households live in neighbourhoods with a socioeconomic profile similar to their own. A low level of segregation in segregation means, on the contrary, that populations with different socioeconomic profiles are living together, in the same neighborhoods. A very abundant literature, particularly in the United States and Europe, has focused on measuring and interpreting the rise and fall of socioeconomic segregation, and especially income segregation.

Our view in this paper is that a natural candidate to explain income segregation may be social housing and we ask the following question: to what extent may income segregation be related to the geographical distribution of social

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\*Université Paris Dauphine

†EDHEC Business School

housing units? So we focus on the dynamics of segregation of not one, but two variables: income and housing tenure status. This is innovative in two ways. First, while the studies on income segregation are numerous, those relating to home tenure (and especially social housing) are extremely rare. However social housing is likely to be a key factor in explaining the geographical distribution of households according to their income. Low income populations are often overrepresented in the social housing sector. At the same time, in many countries, social housing is geographically concentrated on certain areas (due to the construction of large social housing programmes in specific neighborhoods or because local authorities are more or less willing to accommodate social housing in their jurisdiction). So home tenure is correlated with income and is itself a geographically segregated variable. This suggests that income segregation and home tenure segregation are related to each other and should be analyzed simultaneously. Second, there are few studies showing the interactions between two distinct variables in terms of segregation. It is more common to choose one output variable (which measures segregation) and then test causal variables that can explain the segregation dynamics. This practice often raises questions of identification and endogeneity (of supposedly causal variables) that are very difficult to address. Here, we do not pretend to conduct a causality analysis. Our two variables are probably endogenous and we do not intend to exogenize them. However, we will use recent segregation decomposition techniques (Frankel and Volij, 2011) to measure the extent to which these two forms of segregation (income and home tenure) can be linked and dependent on each other.

We work with exhaustive French administrative data from 1999 to 2015 and work at various geographical levels. In France, the social housing sector is quite substantial (more than 15% of French households live there). Although very few studies have focused on measuring the segregation of households living in social housing<sup>1</sup>, this sector has historically been considered highly concentrated geographically. A Law of December 2000 requires large French municipalities with few social housing units to build more of them to improve the *social mix*. As a first step, we measure the evolution of home tenure segregation in order to ascertain the possible effects of the legal framework on the spatial distribution of social housing. We find that home tenure segregation decreased significantly from 1999 to 2015. In a second step, we measure the evolution of income segregation in France. While there are many studies on this subject in the United States (see for example Massey and Eggers, 1993, Jargowsky, 1996, or Bischoff and Reardon, 2014), they are much rarer in France. Many studies assess the residential segregation of occupational categories (Préteceille, 2006) or immigrants (Safi, 2006, Safi, 2009, Pan Ké Shon, 2009), but we are aware of only two studies dealing with income segregation. Vincent et al. (2015) measure income segregation in large French cities over a 8-year period (2001-2008) and exhibit a slight decrease in segregation. Quillian and Lagrange (2016) proceed to a French-US comparison of income segregation in large cities, but with cross-sectional data (they use the French Census

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<sup>1</sup>Verdugo (2011) or Verdugo and Toma (2018) focus on the role of public housing on ethnic segregation.

of 2008) and provide evidence, notably, of a higher segregation in the US than in France. With our sample running from 1999 to 2015, we show that income segregation has slightly increased in France. This is even more pronounced if we focus on low-income households: they are increasingly isolated from the rest of the population. This result is rather puzzling as home tenure segregation is decreasing meanwhile: social tenants are more and more exposed to the rest of the population, but low-income households are more isolated ...

In a third step, we cross-analyze home tenure and income segregation using Frankel and Volij (2011) decomposition techniques to figure out the contradiction between the rising income segregation and the falling home tenure segregation. As a matter of fact, it appears that in some neighborhoods (those covered by the *social mix* Act), the reinforced exposure of social tenants to people living in private housing stock has made it possible to reduce segregation locally, but at the same time we observe a flight effect to certain municipalities not covered by the Act. These municipalities, which do not have an obligation to build social housing (because they are too small or located in small conurbations), have taken in new households from the middle or upper classes. Admittedly, they are less and less numerous (an increasing number of municipalities have to build social housing), but in terms of income, they are drifting away from the municipalities concerned by the Act. So it looks like a side-effect of the legal framework: decreasing segregation in the geographical scope of the law but a flight effect out of it.

## B Data and Method

### B.1 Data

In this study, we use an extremely rich administrative data source: FILOCOM (*Fichier des Logements par Communes* or dwelling files per municipality). It is made up from the housing tax file (*taxe d'habitation*), the land file of built properties (*fichier foncier*), the owners' file (*fichier des propriétaires*) and the personal income tax file. The matching between the housing tax file and the land file is 99% valid. Approximately 1% of the property information is therefore missing only. For mainland France (i.e., excluding the overseas territories), we therefore have nearly complete information on the household income, household profile and tenure (private/social) and location of each dwelling<sup>2</sup> between 1999 and 2015. More specifically, we know the gross income reported by each household to the tax authorities before taxes and transfers<sup>3</sup>. We also know the number and age of people in the household. In the

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<sup>2</sup>Information on household income and size is only available if the dwelling is the household's main residence. We also know if the dwelling is a main or secondary residence and whether it is vacant or occupied.

<sup>3</sup>However, this income is net of payroll charges (employees and employers) which are deducted upfront from the payroll in France.

rest of the study, we will rarely use household income, but rather income per consumption unit<sup>4</sup> in order to take the size of the household into account. Above all, since we are working with pre-transfer and pre-tax data, the definition of income we use is likely to be biased. The structure of grants and allowances for low-income households or tax deductions for high-income households has changed significantly since 1999. As a result, the gap between net and gross incomes is not the same for rich and poor households and has probably evolved differently according to the level of income of the household. For example, if we were to show that the (gross) income gap between the top 10% and the bottom 10% of the population, this does not necessarily mean that inequalities decreased over this period. Net income discrepancies may have widened according to the evolution of the amount of subsidies received by disadvantaged households for instance. To curb this bias as much as possible, and in line with Goux, Maurin, Guyon (2012), we divide the sample into income quintiles<sup>5</sup> (5 ordered groups each comprising 20% of the French population). As the system of aids, deductions and allowances is largely progressive and indexed to income in France, it is extremely likely that the different groups are not very sensitive to the definition of income. In other words, a household belonging to a given group based on gross income is likely to belong to the same group based on net income. Moreover, as will be explained below, segregation indices are not sensitive to income gaps between different groups, but only to differences between the national distribution (20% in each group) and local situations.

We also know the home tenure status of the dwelling (if not vacant). We can therefore distinguish between owner-occupiers and tenants. Among the tenants, we also distinguish social tenants from private tenants. More information will be given afterwards on the different types of home tenure in France (and in particular on the different forms of social housing). Note that, later on, when we discuss the evolution of segregation according to home tenure, we will focus on the binary distinction between social tenants and the rest of the population. Owners-occupiers and private tenants will not be considered separately as it is actually the possible dropout (or on the contrary, catching up) of social tenants that we would like to highlight. The convergence or divergence of incomes between private tenants and owners-occupiers is not the topic of the present study (nor is it the focus of the various national laws aimed at promoting social diversity in France and which target social tenants).

Information about the location of the household is absolutely crucial to our study. We work with three nested geographical levels: the department (*département*), the municipality (*commune*) and the land register unit (*section cadastrale*). The department (the broadest level) is a territorial and administrative division of France as well as a local authority. Metropolitan France is made up of almost 100 departments. It should be noted that part of the subsidies

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<sup>4</sup>We use the EUROSTAT scale to calculate the number of consumption units in the household: 1 unit for the first adult in the household, an additional half point for each person over 14 years and an additional 0.3 point for each person aged 14 years or less.

<sup>5</sup>Other breakdown options (in deciles, with reference to average or median income) will also be tested.

for the construction or renovation of social housing is financed by the departments. It will therefore be interesting to study the evolution of segregation between departments. It is linked to various demographic and economic factors (population growth, unemployment trends, residential mobility), but also to the social housing policy conducted by the local authority. The municipalities are the intermediate level of our analysis. France comprises more than 36,000 municipalities (most of them, around 95%, with less than 5,000 inhabitants and only 2.5% of them with more than 10,000 inhabitants). As detailed below, municipalities are key players in social housing policy. The head (mayor) of a municipality can profoundly influence the number of social housing units available on the territory of the municipality, and thus impact segregation. Studying segregation at the inter-municipal level is therefore particularly relevant since one can imagine situations where some municipalities would "specialize" in social housing, while others would only provide private housing, thereby reinforcing segregation. Finally, the smallest geographical scale we will study is the land register unit. A land register unit is an administrative sub-municipal division designed in order to ease the process of some local taxes collection. The boundaries of a land register unit are constituted, as far as possible, of natural or artificial limits (roads, railways, rivers, etc.). On average, a land register unit consists of about 300 inhabitants (much more in Paris where a land register unit is made of one or several building blocks and much less in the rural areas). As Guyon (2016) points out, the register unit is therefore a more precise geographical area than the "census tract" and even the census block in the United States (with respectively around 4,000 and 1,000 inhabitants on average). From an administrative point of view, the land register unit does not correspond to any political authority. No decisions relative to social housing are taken at the level of the land register unit. However, this detailed geographical scale will allow us to assess the evolution of segregation within the municipality. For example, one could envisage situations where a mayor would decide (according to his campaign promises or to comply with the obligations set by the State) to build or implement social housing in the municipality, but where he/she would decide to carry out this policy in a specific zone (one or several contiguous land register units with already a high proportion of social housing) of the municipality. If the municipality had previously little social housing compared to the national average, then the inter-municipal segregation would be lowered by this political decision, but intra-municipal segregation would grow as the social tenants were concentrated in a given area of the municipality. In this case, the total effect of the political decision on segregation is uncertain and it is therefore crucial to distinguish the inter-municipal level from the intra-municipal level.

The FILOCOM database is enriched every two years by a new cross-section. Data are therefore available for all odd-numbered years from 1999 to 2015. We are working on the long term and only study here the start and end years of the sample<sup>6</sup>, so 1999 and 2015. For each year  $N$ , information with respect to home tenure and household

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<sup>6</sup>Calculations are extremely time-consuming and it would be costly to redo them for years 2001 until 2013.

composition is for January 1<sup>st</sup> of year  $N$ . The reported annual income is for year  $N - 1$ . So, in a way, the results that we highlight trace the evolution of segregation between 1998 and 2014 rather than between 1999 and 2015. We nonetheless decide to keep on working with "odd years" values to comply with the official waves of our administrative data sources.

## B.2 Method

### B.2.1 Mutual information index

There are many segregation indices, the characteristics of which may strongly differ (see, for a survey, Massey and Denton, 1988). For the purposes of this study, we have very specific needs about the desirable properties of the segregation index. First, like Frankel and Volij (2011) or Reardon and Firebaugh (2002), we place ourselves immediately in the context of a multi-group analysis, since the number of groups is more than 2, whereas many indices are only suitable for up to two groups. Second, we want to study segregation at several levels simultaneously (at the department, municipality and land register unit levels), we must take the decomposability properties of the index into account.

We focus on the mutual information index since it satisfies most of the required properties. For a given year, let  $N$  be the total number of households in France. This population is divided into  $K$  units (i.e.,  $K$  land register units) with  $N^k$  the number of households in unit  $k$  ( $k = 1, \dots, K$ ). Let  $G$  be the number of groups (here, income groups). As explained in the data section, the reference is  $G = 5$ . We split the population into five groups of the same size, 20% each (*quintile splitting*). The total number of households belonging to the group  $g$  is  $N_g$  ( $g = 1, \dots, 5$ ) and is the same for each group. We set  $g = 1$  for the "low income" group (bottom 20%),  $g = 2$  for the "middle-low income" group (from first to second quintiles),  $g = 3$  for the "intermediate income" group (from second to third quintiles),  $g = 4$  for the "middle-high income" group (from third to fourth quintiles), and  $g = 5$  for the "high income" group (top 20%).  $N_g^k$  is the number of households in group  $g$  in unit  $k$ .

Two things are important to note. First, since our groups are built on the basis of quintiles, the distance between groups is not taken into account. Thus, it is highly likely that between 1999 and 2015, the income gap between group 1 and group 5 has changed. However, this does not directly affect the segregation index itself, which only depends on the gap between local and national situations. This choice is motivated by the fact that we work with gross rather than net income (see data section). However, to verify the robustness of our results, we will study other group segmentations (notably one where groups are based on the distance to the median income). These complementary analyses are provided in Appendix. Second, having divided the population into several groups *of the same size* will

allow us to decompose the contribution of each spatial unit  $k$  to the overall measure of segregation obtained with the mutual information index.

$p_g$  is the overall proportion of households belonging to income group  $g$ ,  $p_g = N_g/N$  and  $p^k = N^k/N$  is the share of households living in land register unit  $k$ .  $p_g^k = N_g^k/N^k$  is the proportion of group- $g$  households in unit  $k$ .  $P$  is the distribution of the different groups in the population,  $P = (p_1, p_2, p_3, p_4, p_5)$  and  $P^k$  is the distribution of the different groups in unit  $k$ ,  $P^k = (p_1^k, p_2^k, p_3^k, p_4^k, p_5^k)$ .

The mutual information index  $M$  is given by

$$M = h(P) - \sum_{k=1}^K p^k h(P^k) \quad (\text{B.1})$$

where  $h(P)$  is the entropy of the distribution  $P$

$$h(P) = \sum_{g=1}^G p_g \ln \left( \frac{1}{p_g} \right) \quad (\text{B.2})$$

The entropy is always positive and is maximal when all the proportions are equal ( $p_1 = \dots = p_5$ ).  $M$  is equal to zero (*no segregation*) when the distribution of groups in each spatial unit  $k$  is consistent with the national distribution ( $P^k = P$  and hence  $h(P^k) = h(P)$  for all values of  $k$ ). So  $M = 0$  if the size of each of the five income groups is equal to 20% in each unit in France. In contrast, the income segregation is maximal when each land register unit is "specialized" with only households from a single group. So, it would mean that 20% of units only have group 1 (low income) households, 20% only middle low households, etc. In that case,  $h(P^k) = 0$  for each  $k$  and  $M = h(P)$ .

The mutual information index therefore has values from 0 to  $h(P)$ . The maximum value of the index depends on the distribution of the reference population: this may render the interpretation of the index difficult. This is why it is more common to use a standardized version of this index – the Theil index – which is simply equal to the mutual information index divided by its maximum value  $h(P)$ . The Theil index then takes its values between 0 and 1 and we will sometimes calculate it. However,  $M$  has better decomposability properties. Notably, as demonstrated by Frankel and Volij (2011), the mutual information index satisfies the strong school decomposability<sup>7</sup> (SSD), which is a critical property for our purpose.<sup>8</sup>

The SSD property implies that it is possible to decompose additively the total segregation at different levels. For example, let  $X$  and  $Y$  be two unit clusters (these may be geographical areas, departments or municipalities or different sectors, units with a majority of social housing or with a majority of private housing).  $X \cup Y$  is the union

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<sup>7</sup>Frankel and Volij (2011) studied the properties of segregation indices in a school setting. So the spatial unit was the school. In the context of our study, we should talk here about strong unit decomposability.

<sup>8</sup>It also satisfies the strong group decomposability (SGD) property which will not be used here (e.g., Frankel and Volij, 2011).



of these two clusters (all units combined). Let  $c(X)$  (resp.  $c(Y)$ ) be the fictitious unit resulting from the union of all units in  $X$  (resp. in  $Y$ ).  $M$  satisfies the SSD property:

$$M = M(c(X) \cup c(Y)) + \frac{N_X}{N_X + N_Y} M(X) + \frac{N_Y}{N_X + N_Y} M(Y) \quad (\text{B.3})$$

where  $M(X)$  (resp.  $M(Y)$ ) is the mutual information index in cluster  $X$  (resp.  $Y$ ).  $N_X$  (resp.  $N_Y$ ) is the number of households in cluster  $X$  (resp.  $Y$ ). As shown by equation (B.3), the total segregation level,  $M$ , is the sum of three components: the level of segregation between  $X$  and  $Y$ ,  $M(c(X) \cup c(Y))$ , the (weighted) level of segregation within  $X$ ,  $M(X)$ , and the (weighted) level of segregation level within  $Y$ ,  $M(Y)$ . Significantly, the weights depend only on the relative sizes of the two clusters and not on their composition. It is therefore possible to calculate the share of total segregation due to differences between or within clusters. This strong decomposability is an extremely valuable property for our purpose.

It is also of interest to extend the number of clusters. For instance, assume that  $X_1$  is the cluster of units where the share of social is less than 10%.  $X_2$  is the cluster of units where the share of social housing is between 10% and 20%, etc. In this case, the SSD property still applies

$$M = M(c(X_1) \cup c(X_2) \cup \dots \cup c(X_C)) + \sum_{c=1}^C \frac{N_{X_c}}{N} M(X_c) \quad (\text{B.4})$$

where  $C \geq 2$  is the number of clusters. For a complete demonstration, please refer to Frankel and Volij (2011).

Moreover, it is possible to proceed to a nested decomposition of the segregation level. Assume for example that there are two geographical divisions  $A$  and  $B$  (two departments or two municipalities) and two sectors  $X$  and  $Y$  (e.g.,  $X$  is the set of units with more than 50% social housing and  $Y$  with less than 50% social housing). Let  $X_A$  be the set of land register units with a majority of social housing located in  $A$ . Then  $M$  may be expressed as follows

$$\begin{aligned} M = & M(c(A) \cup c(B)) + \sum_{R=A,B} \frac{N_R}{N_A + N_B} M(c(X_R) \cup c(Y_R)) + \\ & \sum_{R=A,B} \frac{N_R}{N_A + N_B} \left[ \frac{N_{R_X}}{N_{R_X} + N_{R_Y}} M(X_R) + \frac{N_{R_Y}}{N_{R_X} + N_{R_Y}} M(Y_R) \right] \end{aligned} \quad (\text{B.5})$$

In the RHS of equation (B.5), the first term corresponds to the level of segregation between regions  $A$  and  $B$  and the second term to the level of segregation between the "social sector"  $X$  and the "private sector"  $Y$  *within the same geographical division*. This term may be compared to  $M(c(X) \cup c(Y))$  in equation (B.3) to see if the geographical scale is relevant when measuring the contribution of the level of segregation between  $X$  and  $Y$  to the national level of segregation  $M$ . The last term in equation (B.5) is the level of segregation between units (here the register unit is the lowest geographical scale) within the same geographical division and the same "sector".

### B.2.2 Other indices

From a statistical point of view, it is important to note that the time evolution of  $M$  might be biased. In fact, even if  $M$  verifies a large number of key properties, it does not fulfill the condition of *composition invariance* (CI hereafter). As explained by Frankel and Volij (2011), the CI property ensures that if the relative sizes of one or more groups change over time, the segregation index remains unaffected. In other words, if between 1999 and 2015 the relative size of groups were to change at the national level, without any change in the local distribution (the size of the group increased in the same proportions in each local unit), then the measure of segregation should not change. The mutual information index does not theoretically satisfy the CI property<sup>9</sup>. Note that this property is not of crucial importance for our study, as we are working essentially with quintiles whose relative size does not change, by construction. Nevertheless, as we also work with groups whose relative size is likely to change (groups constructed with respect to median income for instance), it is also interesting to measure income segregation with indices other than the mutual information index.

Actually, the only indexes matching the CI property in a multi-group (more than 2 groups) context are the Atkinson indices. Atkinson's inequality indices were proposed by James and Taeuber (1985) based on the work of Atkinson (1970) and are defined as follows:

$$A = 1 - \sum_{k=1}^K \left\{ \prod_{g=1}^G (\pi_g^k)^{\omega_g} \right\} \quad (\text{B.6})$$

where  $\pi_g^k = N_g^k/N_g$  is the share of households in unit  $k$  among the group- $g$  households.  $\omega_g$  is a weight given to each group. The weights sum to unity,  $\sum_{g=1}^G \omega_g = 1$ . Most of the time (cf. Massey and Denton, 1988), this index is used in its symmetrical version which is much simpler to interpret:  $\omega_g = 1/G$ . We will be working with this version of the index afterwards. Exactly as with the mutual information index  $M$ , when the proportions of households in each income group are the same in each land register unit (i.e. in the absence of segregation),  $A$  is equal to zero. On the contrary when segregation is maximal, so when there is no more than one income group in each unit, then  $A = 1$ , i.e. the Atkinson's index takes its maximum value. In summary, although the results obtained with  $A$  and  $M$  are often very close to each other, the Atkinson index has two specific advantages: it is invariant to group composition (and therefore its evolution over time is interpretable) and it is normalized (it takes its values between 0 and 1). In contrast, as we mentioned previously, the mutual information index is strongly decomposable, which is not the case with the Atkinson index.

Indices  $A$  and  $M$  look directly at the differences between the local and national distributions of the (here income)

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<sup>9</sup>However, as explained by Givord et al. (2016), the degree of sensitivity of entropy indices in general (and the mutual information index in particular) to a population's composition has been tested empirically and is not significant.

groups. They therefore belong to the family of indices measuring *evenness*. But there is another crucial dimension of segregation: *exposure*. The index of exposure (or oppositely isolation) measures to what extent members of a given group are exposed to their own group rather than to member of other groups. Differently said, this exposure index captures the likelihood that a randomly chosen household of a given group will be exposed to another household of the same group in its land register unit.

The standardized exposure index was first proposed by Bell (1954) in its dichotomous version, and then extended by James (1986) to the multi-group case. Here, we choose to use it in its dichotomous version. So, we will choose a reference group  $\bar{g}$  (alternatively the 20% poorest  $g = 1$  or the 20% richest  $g = 5$ ) and build the normalized exposure index *to this reference group*:

$$E_{\bar{g}} = \frac{1}{p_{\bar{g}}(1 - p_{\bar{g}})} \sum_{k=1}^K p^k (p_{\bar{g}}^k - p_{\bar{g}})^2 \quad (\text{B.7})$$

As explained by Ly, Maurin and Riebert (2014),  $E_{\bar{g}}$  may be interpreted as the share of variance in the share of households who belong to group  $\bar{g}$  explained by the inter-unit heterogeneity. Another - less technical - interpretation is: let  $\mu^1$  be the average exposure of group- $\bar{g}$  households to their own group and  $\mu^0$  be the average exposure of the rest of the population to the group- $\bar{g}$  households, then we have

$$E_{\bar{g}}(X) = \mu^1 - \mu^0 \quad (\text{B.8})$$

The normalized exposure index is then equal to the difference between the exposure to the reference group of households in that group and that of households in other groups. Moreover, on average, households in a group cannot be less exposed to their own group than others (since everyone is already exposed to himself, i.e. to a household in his group),  $E_{\bar{g}} \geq 0$ . When each register unit reproduces the national distribution of groups (homogeneity), everyone has the same exposure to the reference group ( $\mu^1 = \mu^0$ ) and therefore  $E_{\bar{g}} = 0$ . On the contrary, in a situation of full segregation, i.e. when all the households in the reference group are grouped together in some specific units and the rest of the individuals in other units, then we have  $\mu^1 = 1$ ,  $\mu^0 = 0$  and therefore  $E_{\bar{g}} = 1$ . The index  $E_{\bar{g}}$  thus takes its values between 0 and 1.

We will therefore use the normalized exposure index (to the poorest 20% and also to the richest 20%) to complement the analysis provided by the Atkinson and mutual information indices. Note that in theory the time evolution of  $E_{\bar{g}}$  should be considered with caution, as it is not invariant to composition. However, once again, the relative sizes of the groups we have chosen are inherently stable over time, which offsets this problem. The normalized exposure index is not strongly decomposable. Decompositions according to groups and spatial units will therefore only be carried out with the mutual information index.

### B.2.3 Small sample bias

All of the indices mentioned above are affected by the bias issue due to the small size of the spatial unit. This issue may be summarized as follows. A nil value of the index (either  $M$ ,  $A$ , or  $E$ ) represents complete evenness. However, an important concern is that each of these indices may be strictly positive even when households are allocated randomly across units. This problem is all the more acute the smaller the size of the spatial units. Indeed, as explained by Carrington and Troske (1997), the random allocation of households to (small) units will typically generate some deviation from evenness. Some very small units will be allocated individuals from only one (or maybe only two groups) instead of being allocated a uniform distribution of the five groups as expected. Differently said, evenness ( $M = 0$ ) is not randomness ( $M > 0$ ). So, in line with Carrington and Troske (1997), we will measure a sample's distance from randomness rather than its distance from evenness. We will therefore calculate the measure of segregation in the population and compare it to the (random) measure obtained by reallocating households in the land register units by bootstrap techniques. Given that this bias issue is actually prevalent for very small units only, we will use the bootstrap at the scale of the land register unit (which, has only a few hundred individuals) and not at the scale of the municipality or department (which are much broader). The bootstrap is therefore conducted by randomly reallocating households to other land register units of the same municipality (and thus within the same department). We obtain a random value,  $M_{bootstrap}$ , which will be compared to the population measure of  $M$ . The distance between the two indices is a bias-corrected measure of segregation.

## C Social Housing

### C.1 The French context

Let us now present the French situation in detail. As we have said, the social housing sector is particularly important in France (between 15% and 17% of the French population resides there, depending on the definition used<sup>10</sup>). By social housing, we mean here exclusively social *rental* housing, i.e., dwellings with capped rents.

Access to social housing in France is determined by the household composition (number of people) and resources (income ceiling) and the location of the dwelling<sup>11</sup>. The income ceiling depends in particular on (1) the dwelling category and (2) its location. There are three types of dwelling categories : the "high-income ceiling" category (PLS

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<sup>10</sup>In fact, depending on whether or not local authority-owned social housing is taken into account, the figure rises from around 15% to almost 17%.

<sup>11</sup>Notice that certain people, given their personal situation, may be given priority.

*Prêt Locatif Social*), the "middle-income ceiling" category (PLUS, *Prêt Locatif à Usage Social*), the "low-income ceiling" category (PLAI, *Prêt Locatif Aidé d'Intégration*). The PLS category accounts for 7.2% of the social housing stock and nearly 80% of the French population is eligible for it. It is therefore largely dedicated to middle-class households. The PLUS category is by far the most important category: nearly 90% of the social housing stock. Approximately two thirds of the French population have incomes below the PLUS ceiling. The PLAI category (3.7% of the social housing stock) mainly concerns low income households: barely one French household out of 3 may apply for it<sup>12</sup>. Unfortunately, our data source does not distinguish between the three categories of social housing (PLS/PLUS/PLAI). However, we do know the income of the household that occupies the dwelling, which is more important for our purpose.

Rent ceilings vary according to the dwelling category. For example in Paris in 2016, the maximum monthly rent per m<sup>2</sup> is equal to 9.14€ for a PLS, 6.09€ for a PLUS and 5.42€ for a PLAI. These rents are much lower than those in the private rental sector. Indeed, in 2017, the average monthly rent in the private sector is 580€ compared to 400€ in the social rental sector, all categories combined (USH, 2018).

Social landlords are responsible for the construction and management of the social rental stock. For the production of social housing, the social landlord receives financing from a public state bank (CDC, *Caisse des Dépôts et Consignation*) with very attractive subsidized rates. Credit rates vary according to the category of social housing: they are lower for a PLAI dwelling than for a PLUS dwelling, themselves lower than for a PLS dwelling. There are different types of social landlords: public social landlords (OPH, *Office Public de l'Habitat*) and private social landlords (ESH, *Entreprise Sociale pour l'Habitat* and SEM, *Sociétés d'Economie Mixte*). Private social landlords enjoy a little more freedom in their mode of operation (allocation and management of social housing) with respect to the political objectives of local authorities than public social landlords. Nevertheless, all social landlords are subject to the same regulations (same income ceilings, same credit rates). We therefore decide not to distinguish between these different types of landlords and to study social rental housing as a whole.

While social landlords are a key player in the production of social housing, the role played by municipalities should not be neglected (Chapelle and Ramond, 2018). Indeed, municipalities (or groups of municipalities) draw up the Local Urban Plan (PLU, *PLan Local d'Urbanisme*<sup>13</sup>). A PLU is a strategic text containing guidelines for the municipality development over the next 10 to 15 years. It is also a regulatory document governing the evolution of each land register unit of the municipality, in particular through the processing of building and demolition permits.

<sup>12</sup>These are simple averages since income ceilings vary according to the location of the dwelling.

<sup>13</sup>In fact, the PLU is less and less the prerogative of municipalities. PLUs are now often inter-municipal: they are established by an organisation grouping together various neighboring municipalities.

Hence, municipalities have control over the granting of building and demolition permits, which allows them to influence the decisions of real estate developers and social landlords. In addition, municipalities also have a preemptive power. This means that the owner of a dwelling located in an area defined by a local authority (municipality or group of municipalities) as strategic to carry out urban development operations must, first and foremost, offer to sell the property to this authority. Thus the municipality has the possibility, under certain conditions defined in the PLU, to buy back a property currently on the market and, for instance, to convert it into social housing (with the support of a social landlord). In addition, municipalities have, most of the time, even more direct means of exerting influence on the decisions of social landlords: they often act as guarantors for the loans granted to landlords (and as such have a right of control over the housing programme financed by the loan). Finally, municipalities are also represented on (and often even chair) the boards of social landlords. All these elements show that, undoubtedly, municipalities play a key role in social housing construction policy in France.

Overall, the decision to build social housing can be taken by many actors: municipalities and/or social landlords as we mentioned previously, but also other local authorities (especially departments) or the State. The implementation can be financed by these different actors depending on the housing objectives. First of all, the State may, in addition to the assistance indirectly provided to social landlords through subsidized loans (CDC loans, see above), decide to grant tax cuts (reduced rate VAT, property tax exemption, corporate tax exemption, etc.) to social housing construction programmes or, much more rarely, direct subsidies. In addition to the State, some local authorities, especially departments, participate in the construction of social housing through direct subsidies to social landlords. According to recent figures provided by the Housing Accounting Entity, the amounts of these subsidies from local authorities is close to 1.4 billion euros<sup>14</sup> in 2013 (compared to more than 22 billion euros provided by the State in the form of tax benefits, direct subsidies or subsidized rates). Moreover, in some cases, departments (but also municipalities or groups of municipalities) can ensure the distribution of State funds (local delegation of a State authority). To sum up, it appears clearly that the production and financing of social housing in France relies on many different actors: the State, the departments, the municipalities, the social landlords.

In addition, decisions concerning the allocation of social housing are also fragmented: one third of newly built social housing is assigned to the municipalities' quota (the municipalities decide to which household these housing units will be assigned), another third is assigned to the State (and sometimes delegated to the departments) and finally the last third is assigned to social landlords. This, again, fully justifies our decision to analyze the evolution of segregation in France at different geographical levels simultaneously (national / department / municipality).

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<sup>14</sup>These subsidies are rather difficult to record and consequently are likely to be underestimated.

## C.2 The SRU Act

Enacted on December 14, 2000, the SRU (*Solidarité et Renouvellement Urbain*) law is a major reform that overturned the rules of urban planning in France. The law puts in place a number of measures in order to favour local and urban planning mix in certain municipalities with regard to building construction, in particular with the PLU. The law was developed around three requirements: (1) a greater solidarity, (2) encouraging sustainable development, (3) the strengthening of democracy and decentralization. In line with the first requirement, the famous Article 55 of the SRU Act aims to ensure a homogenous distribution of the social housing stock throughout the country with a view to reducing social segregation and meeting the needs of low-income households. This article requires certain municipalities in large urban areas and/or with high housing prices to have a minimum number of social housing units, proportional to their residential stock.

More precisely, municipalities with more than 3,500 inhabitants (1,500 inhabitants in the Paris conurbation) belonging to agglomerations or inter-municipalities with more than 50,000 inhabitants, including at least one municipality with more than 15,000 inhabitants, must have at least 20% social housing. The law was reinforced in 2013 and this rate increased from 20% to 25% for certain municipalities. In all, just over 1,000 municipalities<sup>15</sup> are concerned by the SRU Act. Every year, the State makes an inventory of the municipalities that are falling short of their targets. Municipalities which do not reach the target rate (20% or 25%) set by law are liable for an annual levy, proportional to the number of missing housing units, taking into account the financial situation of the municipality. Notice that many municipalities are exempt from this annual levy.

In addition to the inventory, the State sets a catch-up obligation every three years. Municipalities are set a minimum number of social housing units to be built or financed over the three-year period. At the end of each three-year period, a report is drawn up and the municipalities that have not met their objectives may be penalized (through an increase in the annual levy). Thus, at the end of the three-year period 2014-2016, 649 municipalities had not reached their production levels set by the SRU law (less than 20% or 25% social housing) and, among them, 269 municipalities were fined (they did not meet their three-year period building requirements).

The subject of this study is not an impact assessment analysis of the SRU Act. No causal interpretation analysis will be implemented here. Rather, our objective is to study the evolution of income segregation in France between 1999 and 2015, and to quantify the role of the social rental housing sector. However, we should expect the SRU law to impact social segregation through its expected consequences on the geographic distribution of social housing. Moreover, the time frame we are working on covers the period covered by the SRU Act. As of 1999, the SRU Act had

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<sup>15</sup>1,152 in 2014 more precisely. The total number of municipalities in France is close to 36,000.

not yet been passed into law. Our results in 1999 (measuring income and home tenure segregation) can therefore be seen as a picture of France before the law. In 2015, fifteen years after its enactment, most of the effects of the SRU law are supposed to be visible. It will therefore be particularly interesting to see whether segregation has decreased in France and thus whether the objective of the SRU law has been achieved.

It should be noted that our study covers the entire French territory and not only the 1,152 municipalities targeted by the SRU law. Indeed, we expect the effects of the SRU law to go beyond its geographical scope (large municipalities in large conurbations). Through residential mobility (households deciding to leave a municipality that builds social housing, households arriving in a municipality where they have found social housing, etc.), income segregation in municipalities not targeted by the SRU law is likely to be impacted.

## D Descriptive statistics

In 2015, we have 28.56 million primary residences in France according to our data source<sup>16</sup>. Of these, there are 4.36 million social rental dwellings (15.22%). The remaining 84.78% is made up of private rental dwellings (around 27%) and owner-occupiers (around 58%). As explained in the data section, we will not distinguish between these last two categories and will only focus on the distinction between social rental housing and the private sector (rented + owner-occupied combined). It is worth noting that the rate of social housing has hardly changed in 16 years. The percentage of social tenants in France was 15.91% in 1999 and 15.22% in 2015. The SRU law has therefore not led to a significant increase in the rate of social tenants. As we shall see later, the municipalities with little social housing initially (and therefore, for some of them, falling short of the objectives of the SRU law) have experienced an increase in their social tenant rates from 1999 to 2015. But, meanwhile, the municipalities with a lot of social housing in 1999 experienced a decrease in their social tenants rate.

Table 1 describes the evolution of the real income between 1999 and 2015 according to the home tenure status of the household. Notice that the real income in level is only poorly informative as it does not control for the size of the household. So if we focus on the real income per consumption unit, we observe that the income gap between social and private sectors was 73.92% in 1999 and is as high as 94.93% in 2015. The evolution is similar with the income level, so it is not related to a change in the household composition in the social housing compared to the private housing sector. Over this time period, social tenants have thus become poorer relative to other households.

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<sup>16</sup>Secondary residences and vacant dwelling have been excluded.



Table 1. Average income according to home tenure

Income	Social Tenant		Private Sector		All Households	
	1999	2015	1999	2015	1999	2015
Income	14,581€	18,501€	26,247€	36,815€	24,389€	34,026€
Income per CU	9,038€	11,746€	15,719€	22,897€	14,655€	21,199€

*Note: real income (constant 2005 euros). CU is for consumption unit. Private sector is private tenants + owners-occupiers*

The analysis of the *average* of income is far too limiting for our study. Indeed, we will calculate segregation by dividing the distribution of income by quintiles in the next section, and some of these effects are not captured by a simple average. Table 2 describes the evolution of income distribution (per deciles) according to home tenure. As expected, the share of private tenants (or homeowners) in the bottom 10% of the income distribution is much lower than its social tenants counterpart (8.17% vs 19.58% in 1999). The gap is even wider in 2015 (7.37% against 24.65%). In line with the previous table, social tenants have become relatively poorer over the considered time period. Their share in the bottom 10% rose from 19.58% to 24.65% and their share in the top 10% declined from 1.57% to 1.02%. This result is fully consistent with the results of the literature on the social rental stock in France (see USH, 2018). The former residents of the social rental housing stock have been gradually replaced by new, poorer tenants. Thus, in the course of 16 years, we estimate that 80% of the social housing units have changed occupants at least once (80% movers and 20% stayers approximately between 1999 and 2015). In 2015, the share of "movers" belonging to the bottom 10% of the national income distribution is as high as 27.49%. while the share of "stayers" is only 13.56%.<sup>17</sup> Accordingly, the share of movers in the top 10% national income distribution is only 0.76%, while 2% for stayers. Therefore, the composition of the social rental stock has profoundly changed over this period and this is generally attributed to a new law introduced in France in 2007, concerning the enforceable right to housing (DALO, *Droit au Logement Opposable*). According to this law, a household having difficulties in finding decent housing can sue the French State to assert its right to housing. Since 2007, the social housing quota reserved for the State (see previous section) has often been used to enforce this law and thus allocate social housing to severely deprived households.

<sup>17</sup>These results are not reproduced in a table here, but are available upon request.

Table 2: Income distribution according to home tenure

Decile	1999		2015	
	Social Tenant	Private Sector	Social Tenant	Private Sector
D1	19.58%	8.17%	24.65%	7.37%
D2	16.15%	8.79%	19.62%	8.32%
D3	13.68%	9.27%	14.20%	9.22%
D4	11.74%	9.65%	11.42%	9.73%
D5	10.49%	9.89%	9.51%	10.08%
D6	9.44%	10.11%	7.51%	10.45%
D7	7.62%	10.47%	5.76%	10.77%
D8	5.93%	10.80%	4.14%	11.06%
D9	3.80%	11.22%	2.53%	11.36%
D10	1.57%	11.63%	1.02%	11.63%

*Note: D1 means below the first decile, D2 means between deciles 1 and 2, etc.*

*Private sector is private tenants + owners-occupiers*

To complement this analysis, we track changes in the number of (high- or low-) income or social housing enclaves between 1999 and 2015. So we count the number of land register units with more than 20, 30 or 40% of low-income or high-income households (i.e., below the first decile or above the ninth decile) over this time period. We do the same for land register units with at least 10 to 60% of social tenants. Results are available in Tables 3a and 3b.

Table 3a. Share of low and high income land register units

Share of impoverished units	1999	2015	Share of high-income units	1999	2015
More than 20% lower than D1	8.97%	10.47%	More than 20% higher than D9	12.55%	12.80%
More than 30% lower than D1	2.37%	3.18%	More than 30% higher than D9	5.24%	5.82%
More than 40% lower than D1	0.56%	0.96%	More than 40% higher than D9	2.19%	2.29%

We see that the number of poverty enclaves increased quite significantly between 1999 and 2015. The number of land register units with more than 20% of households in the poorest 10% increased from 8.97% to 10.47%. The relative increase is even more dramatic for enclaves of very high poverty (more than 40% of households below the first decile): 0.56% to 0.96%, a 71% increase. The spatial concentration of poverty is therefore increasing. We obtain similar results for rich enclaves (increase in their geographical concentration) but to a lesser extent.

Table 3b Share of social tenants enclaves

	1999	2015
More than 10% of social tenants	38.39%	39.67%
More than 20% of social tenants	27.35%	26.63%
More than 30% of social tenants	20.29%	18.72%
More than 40% of social tenants	15.19%	13.30%
More than 50% of social tenants	11.34%	9.67%
More than 60% of social tenants	8.32%	6.74%

*Note: the first line gives the percentage of land register units with more than 10% social tenants*

We are also interested in the number of social housing "enclaves", i.e. the number of land register units with more than a certain percentage (10%, 20%, ..., 60%) of social tenants. We recall that the national average is between 15% and 16% of social tenants. First of all, we note that the share of land register units with more than 10% social tenants increased between 1999 and 2005 (from 38.39% to 39.67%). This seems to be related to the implementation of the SRU Act. Many municipalities now have to reach a target of 20 or 25% of social housing. The majority of these municipalities have built or renovated new social housing to reach their target, which explains the decline in the number of units (and therefore municipalities) with very few social housing units. However, we note that the number of enclaves with a lot of social housing (more than 20%) is decreasing. This is all the more true as the initial concentration of social housing is extremely high (more than 60% for instance, with 8.32% in 1999 and only 6.74% in 2015). Again, this may have something to do with the SRU Act. Some municipalities that have already met their objectives may have slowed down their action with respect to social mix and not much social housing has been built there (or at least not at the same pace as private housing). Globally, it therefore seems that the geographical distribution of social housing has become much more homogenous in France since 1999, with both fewer areas without social housing and areas with an overconcentration of social housing. This is a convergence towards the average phenomenon. This is in line with the results of Verdugo and Toma (2018) who provided evidence of a decrease in the share of public housing enclaves from 1999 to 2012, based on national census data.

## E Results

### E.1 Home tenure segregation

We first evaluate *home tenure* segregation. We measure the extent to which the distribution of social versus private housing may differ locally from its national counterpart. We use the three types of indices presented in the methodology section: the mutual information index  $M$ , the Atkinson index  $A$  and the exposure index  $E$  (here it measures exposure to households living in social housing). For each index, segregation is measured at three distinct geographical levels: the department, the municipality, and the land register unit (from the widest to the smallest). For the finest geographic level (i.e., the cadastral section), we also calculate the level of segregation when households are randomly reallocated into land register units within the municipality they live in. The results are summarized in Table 4.

Table 4 - Home Tenure Segregation in 1999 and 2015  
with bootstrap correction

Segregation	Geographical	Year	
Index	Level	1999	2015
$M$	Department	0.0107	0.0139
$M$	Municipality	0.0629	0.0584
$M$	Land Register Unit	0.1534	0.1366
$M$	<i>Municipality (bootstrap)</i>	<i>0.0772</i>	<i>0.0720</i>
$A$	Department	0.0243	0.0343
$A$	Municipality	0.1754	0.1638
$A$	Land Register Unit	0.4559	0.4218
$A$	<i>Municipality (bootstrap)</i>	<i>0.1867</i>	<i>0.1768</i>
$E$	Department	0.0256	0.0336
$E$	Municipality	0.1367	0.1301
$E$	Land Register Unit	0.4263	0.3781
$E$	<i>Municipality (bootstrap)</i>	<i>0.1404</i>	<i>0.1391</i>

We begin with a cross-sectional analysis of the table. In 1999, the level of segregation was 0.0107 between departments, 0.0629 between municipalities, and 0.1534 between land register units with the mutual information

index.<sup>1819</sup> As explained in the methodology section, due to the strong decomposability property of  $M$  and the nested hierarchical structure of geographical levels, these three values may be compared to each other. Hence, If we consider segregation at the municipal level (i.e., 0.0629), we can say that about 17% ( $0.0107/0.0629$ ) of it is explained by differences *between* departments while the rest (83%) is due to differences between municipalities *within the same department*. If we go down to the scale of the land register unit, we can again break down the measure of segregation (0.1534) into three components: an inter-departmental component (6.98%), an inter-municipal and intra-department component (34.03%) and an inter-register unit and intra-municipality component (59%). Actually, this analysis can be further refined to take into account the bias of small units when measuring segregation at the land register unit level. The gap between segregation at the municipality level (0.0629) and at the unit level (0.1534) should not incorporate the component ( $0.0772 - 0.0629$ ) linked to the allocation bias. So if we drop this component, we get the following split of segregation: 7.69% between department, 45.22% between municipalities but within departments, and 47.09% between units but within municipalities. Thus almost half of the segregation obtained is linked to local differences: due to differences in the social/private distribution of land register units located in the same municipality. In other words, there appears to be more discrepancies between the social housing shares of two randomly selected units in the same municipality than between two randomly selected municipalities or departments. Segregation is a local phenomenon in France. We get similar result with the other indices  $A$  and  $E$ , though these should be considered with more care as these indices do not satisfy the strong decomposability property.

Now we proceed to a longitudinal analysis of the results. As might be expected given the descriptive statistics outlined above, home tenure segregation fell sharply between 1999 and 2015, regardless of the index considered, at all geographic levels, departments being excepted. Thus, according to the mutual information index, segregation between municipalities has decreased by more than 7% since 1999 (from 0.0629 to 0.0584). Even more interestingly, the pace of decline in segregation is even faster at the land register unit level (almost 11%, from 0.1534 in 1999 to 0.1366 in 2015). These results are also confirmed using the Atkinson index which satisfies the composition invariance property and as such can be interpreted longitudinally (a 6.61% decrease at the municipal level and a 7.42% decrease at the local unit level).

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<sup>18</sup>These values should not be interpreted in level as they are not normalized. However, it is possible to standardize them to get the normalized entropy index by dividing each expression by  $h(P) = \sum_{g=1}^2 p_g \ln\left(\frac{1}{p_g}\right)$  where  $p_1 = 0.1591$  being the share of social housing and  $p_2 = 1 - p_1$  the share of private housing. So  $h(P) = 0.4382$ . Consequently, the department segregation level is 2.44%, the municipal level is 14.36%, and the land register unit level is 35.01%.

<sup>19</sup>Notice that the segregation measure mechanically increases as the geographical level gets smaller.

This general decrease in segregation can be linked to the SRU Act<sup>20</sup>. Regional and local disparities have narrowed. The rate of social housing in municipalities and land register units in France has come close to the national average. Municipalities initially below the national average built more social housing and those above built relatively less, resulting in a more homogeneous geographical distribution of social housing across municipalities. Most importantly, SRU enforcement appears to have avoided a trap: municipalities falling short of the objectives of the law could have tried, while building social housing, to distribute these new dwellings unevenly over their jurisdiction with the new social housing clustered over a portion of the municipality, and private housing on another portion. If true, this would allow municipalities to hinder social mix which is sometimes feared by part of the population. Our results show that this is not the case: segregation between land register units of the same municipality has decreased sharply since 1999. Social housing is more evenly distributed within municipalities.

## E.2 Income segregation

We now turn to the measurement of income segregation. The income distribution is broken down into quintiles.<sup>21</sup> We perform the same calculations as in the previous subsection (three indices, spatial breakdown, bootstrap) except that a new "geographical" step is added: the distinction between social housing and private housing within the land register unit. This step allows us to measure the income discrepancy between social tenants and households living in private housing at the land register unit level. So here we have four nested geographical levels: between departments, between municipalities (within the department), between land register units (within the municipality), between sectors (within the land register unit). Note that this last step does not correspond exactly to a measure of segregation. Indeed, within a local register unit, private and social housing are not necessarily separated. The two sectors spatially intersect.<sup>22</sup> As a result, households living in each of the sectors cohabit and we cannot consider measures of  $M$ ,  $A$  or  $E$  as a level of spatial separateness between these two populations, but only as a measure of the extent to which two groups of households living in the same neighborhood may see their income levels move towards or away from each other. The overall results are summarized in Table 5.  $E_b$  stands for the index of exposure to the bottom 20% of the income distribution and  $E_t$  for the exposure index to the top 20%. Notice that we have to conduct two bootstrap procedures for each segregation index : in the first one (*municipality bootstrap*), households are randomly reallocated in a land register unit of their municipality and in the second one (*register unit bootstrap*), they are randomly reallocated in *housing sector* of their land register unit.

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<sup>20</sup>Though, once again, we do not make any causal analysis.

<sup>21</sup>A decile distribution and a median-relative group distribution have also been tested. Results are qualitatively similar (see Appendix).

<sup>22</sup>They may even intersect at the building level with private and social flats in the same building.

Table 5 - Income Segregation (quintiles) in 1999 and 2015

Segregation	Geographical	Year	
Index	Level	1999	2015
$M$	Department	0.0285	0.0248
$M$	Municipality	0.0612	0.0624
$M$	Land Register Unit	0.1142	0.1174
$M$	<i>Municipality (bootstrap)</i>	<i>0.0823</i>	<i>0.0825</i>
$M$	Land Register Unit $\times$ SH	0.1430	0.1552
$M$	<i>Register Unit (bootstrap)</i>	<i>0.1292</i>	<i>0.1324</i>
$A$	Department	0.0271	0.0233
$A$	Municipality	0.0609	0.0611
$A$	Land Register Unit	0.1286	0.1287
$A$	<i>Municipality (bootstrap)</i>	<i>0.0827</i>	<i>0.0828</i>
$A$	Land Register Unit $\times$ SH	0.1697	0.1838
$A$	<i>Register Unit (bootstrap)</i>	<i>0.1437</i>	<i>0.1439</i>
$E_b$	Department	0.0137	0.0096
$E_b$	Municipality	0.0397	0.0433
$E_b$	Land Register Unit	0.0839	0.0927
$E_b$	<i>Municipality (bootstrap)</i>	<i>0.0567</i>	<i>0.0603</i>
$E_b$	Land Register Unit $\times$ SH	0.1126	0.1366
$E_b$	<i>Register Unit (bootstrap)</i>	<i>0.0991</i>	<i>0.1081</i>
$E_t$	Department	0.0441	0.0413
$E_t$	Municipality	0.0779	0.0797
$E_t$	Land Register Unit	0.1220	0.1247
$E_t$	<i>Municipality (bootstrap)</i>	<i>0.0922</i>	<i>0.0940</i>
$E_t$	Land Register Unit $\times$ SH	0.1415	0.1474
$E_t$	<i>Register Unit (bootstrap)</i>	<i>0.1322</i>	<i>0.1350</i>

We first proceed to some cross-sectional comments of the results in 1999. As in the case of home tenure segregation, most income segregation is observed at a local level (municipal, land register unit or even within the unit). Segregation is mostly a matter of income gaps across neighboring municipalities or neighboring land register

units. This is true regardless of the index used. For instance, with the mutual information index, after the bootstrap bias correction, we find that 30.61% of total income segregation occurs across departments, 35.12% across municipalities (within-departments) and 34.26% across local units (within-municipality).

Regardless of the index used, segregation increased between 1999 and 2015 (except at the department level). Surprisingly, this is the exact opposite of the results of the previous subsection on home tenure segregation. According to the mutual information and the Atkinson indices (calculated on the basis of the five income quintiles), segregation has increased very slightly since 1999 at the municipal level (+2% approximately) and slightly more strongly at the register unit level (+3%). These increases may seem modest over a 16-year period, but they contrast with the fact that meanwhile social tenants are more evenly distributed across the country, especially at a local level. Moreover, the increase is much more pronounced when working with the exposure index  $E_b$  (exposure to low-income households). At the land register unit level,  $E_b$  rose from 0.0839 in 1999 to 0.0927 in 2015, i.e. an increase of 10.49%. This very marked increase suggests that low income households (bottom 20%) are increasingly exposed to other low-income households (relative to the low-income exposure of the rest of the population, i.e., the remaining 80%). In other words, there seems to be a growing territorial separation between low income earners on the one hand and middle and high income earners on the other. Low-income earners increasingly live among themselves, in the same municipalities, or register units. On the other hand, we do not observe such an increase in segregation for the high-income households (the richest 20%) with the  $E_t$  index. The increase in  $E_t$  is rather modest (from 0.1220 to 0.1247 at the land register unit level, so only 2.21%) and comparable to those of  $M$  and  $A$ . There is therefore no very strong tendency for high income households to live among themselves; on the contrary, it seems that we observe a form of social mix between the middle and upper classes since the (limited) increase in  $E_t$  may be due to the (pronounced) increase in  $E_b$ . The segregation of low income households affects  $E_t$  as the poorest 20% cohabit less and less with the richest 20%.

Another important lesson about income segregation comes from the widening gap between social renters and households living in private housing. The mutual information index  $M$  measuring the differences in income between private and social income within the register unit rises from 0.1430 to 0.1552 (+8.53%). We had seen in the descriptive statistics section that social tenants were being impoverished relative to the rest of the population. These new results suggest that this is not a geographical structure effect<sup>23</sup>: income gaps are increasing even within the same neighborhood. So by combining this information with the results from Table 4, we deduce that private and social housing are increasingly homogeneously distributed over the territory and therefore that social tenants and households living in private housing coexist are less and less segregated. At the same time, these two spatially cohabiting populations are

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<sup>23</sup>For instance, it could be due to social tenants living increasingly in poor areas and private tenants in rich areas (so more local homogeneity and more spatial differences).



increasingly dissimilar in terms of income. The combination of these two factors should help to reduce segregation, or at least slow its rise. We have seen that this is not the case: segregation is increasing for all income groups and especially for the lowest. The next section will help us shed some light on this.

## F Dealing with income and home tenure segregation simultaneously

The main question we have to answer now is: why home tenure segregation is decreasing while income segregation is increasing? As we saw in the previous section, this increase in income segregation is based in particular on the isolation of the poorest 20% of households. These households very frequently live in social housing. Home tenure must therefore play a key role in the assessment of the rise in income segregation. We use the strong decomposability property of the mutual information index to break the income segregation into three components : the income segregation between private (*PH*) and social housing (*SH*) sectors, the income segregation within the private housing sector, and the income segregation within the social housing sector. The spatial unit is the land register unit crossed with the housing sector. The results are summarized in Table 6.

Table 6. Income segregation decomposition according to home tenure

Index =  $M$ , Spatial Unit = Land Register Unit  $\times$  SH. Income Quintiles

Index	1999	2015
Total Segregation in France	0.1430	0.1552
Segregation between <i>SH</i> and <i>PH</i>	0.0272 (19.02%)	0.0448 (28.87%)
Segregation within <i>SH</i>	0.1254 (13.95%)	0.1114 (11.18%)
Segregation within <i>PH</i>	0.1140 (67.02%)	0.1103 (59.95%)

As we might have expected in view of the previous developments, it appears that an increasing part of income segregation is due to the intersectoral gaps: income discrepancies between social tenants and households living in the private sector. They represent 19.02% of total income segregation in 1999 and 28.87% in 2015. This is in line with Table 4 which showed an increase in income disparities between social and private housing. Meanwhile, income segregation is declining within each of the two sectors. Within the social housing stock alone (if private dwellings are not taken into account), income gaps across land register units are decreasing. The geographical income disparities

between social tenants have been reduced since 1999. We observe the same phenomenon of spatial homogenization of income for private housing. Globally, income segregation today is much more due to its inter-sectoral component than to its intra-sectoral component than it was sixteen years before.

Table 6 allows us to discuss inter- and intra-sector differences, but it has a flaw: the sum of these components is equal to the value of the  $M$  index at the scale of land register unit  $\times$  housing sector. However, as we said, this value of  $M$  does not correspond exactly to an index of residential segregation, because private and social housing are not geographically distinct. So we need to find some form of  $M$ -index decomposition at the land register unit level (instead of land register unit  $\times$  housing sector). To do so, we break down the land register units according to their share of social housing. We split them into 10 groups: 0%, less than 5%, [5-10%], [10-15%], [15-20%], [20-25%], [25-30%], [30-35%], [35-40%] and more than 40%.<sup>24</sup> We then look at the extent to which income segregation can be explained by differences in the share of social housing in the unit. Results are provided in Table 7.

Table 7. Income segregation decomposition according the share of social housing in the LRU

Index = $M$ , Spatial Unit = Land Register Unit. Income Quintiles		
Index	1999	2015
Total Segregation in France	0.1142	0.1174
Segregation according to the share of $SH$	0.0110	0.0214
	(9.63%)	(18.23%)

The values given in the last line of this table correspond to the  $M(c(X_1) \cup c(X_2) \cup \dots \cup c(X_C))$  component in equation (B.4) where  $c(X_i)$  are the group of units (according to their share of social housing). This component is then compared to the value of  $M$  to get a percentage. In other words, we seek to determine whether segregation in France can be linked to the evolution of income according to the share of social housing in the neighborhood. Does the amount of social housing in my neighborhood determine whether or not local people are rich or poor? The answer is increasingly yes. The share of income segregation explained by differences in the proportion of social housing has increased tremendously: from 9.63% in 1999 to 18.23% in 2015. The income distributions between a land register unit with few social housing units and a unit with many social housing units have moved away from each other since 1999. Units without social housing are getting relatively richer and units with a high share of social housing relatively poorer. How can this result be reconciled with the previous ones? Actually, we have identified two opposite forces: on the one hand, the number of units with very few or conversely, a lot of social housing is getting smaller. There are much more units with a share of social housing close to the national average (i.e., close to 15%). But, at the

<sup>24</sup>We tried other splitting (4 groups, 6 groups, 8 groups) The results are the same qualitatively.

same time, income gaps between units according to their social housing rate are widening (see Table 8). There are fewer and fewer units with 0% or more than 40% social housing, but the remaining units in these two categories have never been so far away from the other units (those with more than 0% and less than 40% social housing) in terms of income distribution. The municipalities targeted by the SRU Act are building social housing and bringing together populations with different income profiles, but other municipalities, not concerned by the law (small cities, or cities with already more than 25% social housing), are moving away from the rest of the population. This may for instance be linked to a flight effect of rich households towards municipalities not concerned by the law (small cities with no or very little social housing) which see their average standard of living increase. This could also be linked to an impoverishment process of municipalities where the share of social housing is very high and which have long since met their SRU Act objectives.

Table 8. Share of rich and poor households in LRU according to the share of SH

Share of Social Housing in LRU	Share of bottom 10%		Share of top 10%		weight	
	1999	2015	1999	2015	1999	2015
0%	8.09%	6.21%	11.14%	11.31%	39.05%	35.42%
>0% ≤5%	8.88%	8.73%	13.55%	13.23%	14.32%	14.85%
>5% ≤10%	9.63%	9.32%	11.41%	11.08%	8.24%	10.06%
>10% ≤15%	9.79%	9.83%	10.66%	10.33%	6.33%	7.44%
>15% ≤20%	9.49%	10.23%	9.62%	9.72%	4.71%	5.60%
>20% ≤25%	9.71%	10.91%	8.87%	9.09%	3.84%	4.43%
>25% ≤30%	9.51%	11.81%	8.54%	8.12%	3.22%	3.48%
>30% ≤35%	10.76%	12.59%	8.04%	7.65%	2.81%	2.92%
>35% ≤40%	10.71%	13.21%	7.50%	7.44%	2.29%	2.49%
>40%	16.20%	20.30%	4.35%	3.92%	15.19%	13.30%

## G Residential Mobility and Social Housing Construction

In order to understand these results, and in particular why income segregation has kept on increasing in France while social housing is getting more evenly distributed over the territory, we need to go into more detail. We need to take a closer look at the composition of the population living in social housing. As we saw in the "descriptive statistics" section, the population of social tenants has changed significantly (i.e., became relatively poorer) between 1999 and 2015. This may be potentially related to two factors: (1) the relative impoverishment of the population – compared to

private tenants or owner-occupiers – that remained in social housing between 1999 and 2015, and (2) the arrival of much poorer new entrants into social housing. We therefore have to distinguish between “stayers” and “movers”. In our database, it is possible to make this distinction, but with certain limitations. We have a unique, longitudinal identifier for the dwelling, but not for the household occupying that dwelling. For the household, we only have the duration of occupancy of the current dwelling. We do not know what the household’s previous dwelling was. Furthermore, the number of years of occupancy of the dwelling is not completely reliable. Indeed, if the composition of the household changes (birth or departure of a child for example), the number is reset to zero. This is due to the fact that we work with data compiled by the tax authorities, which are interested in possible changes in the tax composition of the family (and not only in its residential mobility). As a result, the duration of occupancy is underestimated (and thus the rate of residential mobility is overestimated). Compared to other studies have been carried out on residential mobility, we conclude that the residential mobility rate is overestimated by about 10%, but in a rather homogeneous way (about 10% for each type of household). We therefore decide to use this variable despite its limitations.

We also use a variable related to the age of construction of the dwelling or building. We can thus distinguish between new dwellings (those built ex nihilo between 1999 and 2015), dwellings renovated since 1999 and old dwellings (those built before 1999 and not renovated since). In addition, we are also able to identify dwellings (with or without renovation) whose use has changed (from social to private housing or vice versa).

We therefore analyze the composition (in terms of income) of households living in social housing in 2015 according to:

- their mobility (“stayers” if they were already occupying the dwelling in 1999 and “movers” if they arrived after 1999).
- the age and type of social housing (built since 1999, renovated since 1999, moved from private to social housing since 1999, old social housing).

It should be noted that the construction or renovation of a dwelling almost always implies that the household’s occupancy period is reset to zero. There are therefore "stayer" households (almost) only in old social housing.

The overall results are summarized in Table 9. We analyze the profile of social housing tenants as well as the profile of the households of the land register unit. First of all, if we compare stayers and movers, we see that the former are much richer than the latter. The proportion of stayers in the first quintile is only 27.53%. This is much lower than what we observe for the different types of movers. Households that have recently moved into social housing (without being able to determine whether they came from social, private, or new housing) have lower incomes on average.

This is in line with the fact that incomes in social housing have fallen since 1999 (moreover, we have shown that new occupants of social housing are more frequently below the first quintile than previous occupants – results are available upon request). However, it is worth noting that while movers are less wealthy on average than stayers, this is not true for their environment. Their exposure to people below the first quintile is roughly the same as for stayers (32.15% compared to 30.85% when comparing old social housing – it is even lower for movers in new social housing units). Thus, the "movers" - poorer - were mixed with the same type of population as the "stayers" - richer. This contributes to the social mix and should therefore have led to a decrease in income segregation. The problem is that while this stayers vs movers distinction, both taken as a whole, seems to have helped reduce segregation, things are less favorable if we zoom in on the different categories of "movers". Indeed, it seems that new construction has, on average, been built in richer environments than other social housing. The households that moved into these new social housing units were themselves wealthier than the other social tenants. The new social housing units were built in cities that were lagging behind the objectives of the SRU Act and which were generally fairly rich cities. Between 1999 and 2015, these cities hosted households that were wealthier than the national average for other social tenants. This combination of wealthier-than-average households, exposed to wealthier-than-average households is a source of segregation. On the other hand, the cities that have refurbished their social housing units are poorer than the average and ... have taken in poorer than average households in these renovated social housing units. This low-income-households in a low-income environment is another factor raising segregation.

Table 9. Profile and exposure of social tenants

Category	Share below Q1	Exposure to <Q1	weight (% of ST)
New Building (Movers)	39.55%	24.02%	15.91%
Renovated Building (Movers)	51.48%	32.48%	6.95%
Ancient Private Dwelling (Movers)	41.11%	27.83%	5.55%
Old social dwelling (Movers)	50.12%	32.15%	54.55%
Old social dwelling (Stayers)	27.53%	30.82%	17.04%

## H Counterfactual Simulation Exercise

Overall, therefore, it seems that the effect of the distribution of households that have moved into social housing since 1999 on income segregation is ambiguous. It seems that the arrival of new households in social housing (movers) who are less wealthy than their predecessors should help to reduce segregation. On the other hand, some of the richest movers have moved into relatively wealthy neighborhoods (new construction, private housing converted into social

housing), while some of the less wealthy have moved into relatively poor neighbourhoods (renovated or old housing) and this hampers the curbing of segregation.

To resolve this ambiguity, we conduct a counterfactual simulation exercise. From the results in Table 9, we have seen that the spatial allocation of movers into social housing is probably not random and that this may have contributed to segregation. In order to ascertain this, we carry out a bootstrap exercise in several steps: we randomly reallocate the "movers" households

- all over the territory (movers are reallocated within the national stock of social housing occupied by movers)
- in their department (reallocation within the department's stock).
- in their municipality (reallocation within the municipality's stock).

Our objective is to see what would have been the impact on segregation of a "blind" system of social housing allocation. As mentioned in the section on social housing in France, the State, the departments and the municipalities participate in these allocation commissions. Each therefore has lists of applicants for social housing, which they can therefore allocate within their geographical territory - within the limits of the quotas at their disposal of course. It therefore makes sense to reallocate households to these three geographical areas in order to measure the gap with the choices made by the State, departments and municipalities.

Note that this simulation exercise does not, of course, affect households living in private housing but neither does it affect stayers in social housing. These households have not left their homes since 1999 and have therefore not been affected by the choices made by the allocation commissions since that date. Only movers (into social housing) are concerned. Each mover is re-allocated the social housing of another mover in its municipality, department, or throughout the national territory.

The results show unequivocally that random assignment would have significantly reduced segregation. If the allocation of new entrants had been done randomly throughout France since 1999, the income segregation would only be 0.1067 instead of 0.1174 (i.e. a reduction of 9.11%) with the mutual information index. The fall in income segregation is even more pronounced with the index of exposure to the bottom 20% incomes (22.10%). Even if reallocation is limited to the department or municipality level, the decrease in segregation remains significant. Thus, the  $M$  index would have been equal to 0.1136 instead of 0.1174 (-3.24%) if the commissions had randomly allocated social housing within the municipality (-9,60% with the "bottom" exposure index). These results show the non-random nature of allocation commissions and their non-negligible effect on income segregation.

Table 10. Random allocation of social tenants

Spatial Allocation	$M$	$A$	$E_{Q1}$	$E_{Q5}$
Whole Country	0.1067	0.1187	0.0722	0.1193
Within-department	0.1099	0.1225	0.0777	0.1114
Within-municipality	0.1136	0.1260	0.0838	0.1234
Observed Value	0.1174	0.1287	0.0927	0.1247

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# I Appendix A (income segregation - deciles)

Table A1 - Income Segregation (deciles) in 1999 and 2015

Segregation	Geographical	Year	
Index	Level	1999	2015
<i>M</i>	DEP	0.0316	0.0283
<i>M</i>	Municipality	0.0726	0.0749
<i>M</i>	Land Register Unit	0.1513	0.1552
<i>M</i>	Land Register Unit $\times$ SH	0.1857	0.1994
<i>A</i>	DEP	0.0294	0.0260
<i>A</i>	Municipality	0.0765	0.0763
<i>A</i>	Land Register Unit	0.2111	0.2132
<i>A</i>	Land Register Unit $\times$ SH	0.2772	0.2956
<i>E (Q1)</i>	DEP	0.0077	0.0062
<i>E (Q1)</i>	Municipality	0.0260	0.0339
<i>E (Q1)</i>	Land Register Unit	0.0621	0.0739
<i>E (Q1)</i>	Land Register Unit $\times$ SH	0.0837	0.1062
<i>E (Q5)</i>	DEP	0.0379	0.0394
<i>E (Q5)</i>	Municipality	0.0696	0.0749
<i>E (Q5)</i>	Land Register Unit	0.1089	0.1138
<i>E (Q5)</i>	Land Register Unit $\times$ SH	0.1209	0.1282

Table A2. Income segregation decomposition according to home tenure

Index = *M*, Spatial Unit = Land Register Unit  $\times$  SH. Income Deciles

Index	1999	2015
Total Segregation in France	0.1857	0.1994
Segregation between <i>SH</i> and <i>PH</i>	0.0288 (15.51%)	0.0467 (23.40%)
Segregation within <i>SH</i>	0.1615 (11.49%)	0.1512 (8.92%)
Segregation within <i>PH</i>	0.1562 (73.00%)	0.1529 (67.66%)

## J Appendix B (income segregation - income classes with respect to median income)

Table B1 - Income Segregation (income classes) in 1999 and 2015

Segregation	Geographical	Year	
Index	Level	1999	2015
<i>M</i>	DEP	0.0290	0.0259
<i>M</i>	Municipality	0.0621	0.0639
<i>M</i>	Land Register Unit	0.1155	0.1192
<i>M</i>	Land Register Unit $\times$ SH	0.1440	0.1563
<i>A</i>	DEP	0.0337	0.0328
<i>A</i>	Municipality	0.0728	0.0780
<i>A</i>	Land Register Unit	0.1536	0.1636
<i>A</i>	Land Register Unit $\times$ SH	0.2060	0.2337
<i>E (Q1)</i>	DEP	0.0158	0.0107
<i>E (Q1)</i>	Municipality	0.0436	0.0452
<i>E (Q1)</i>	Land Register Unit	0.0891	0.0955
<i>E (Q1)</i>	Land Register Unit $\times$ SH	0.1193	0.1407
<i>E (Q5)</i>	DEP	0.0406	0.0404
<i>E (Q5)</i>	Municipality	0.0731	0.0765
<i>E (Q5)</i>	Land Register Unit	0.1144	0.1167
<i>E (Q5)</i>	Land Register Unit $\times$ SH	0.1288	0.1325

Table B2. Income segregation decomposition according to home tenure

Index =  $M$ , Spatial Unit = Land Register Unit  $\times$  SH. Income Classes

Index	1999	2015
Total Segregation in France	0.1440	0.1563
Segregation between $SH$ and $PH$	0.0273 (18.96%)	0.0441 (28.21%)
Segregation within $SH$	0.1214 (12.26%)	0.1064 (10.01%)
Segregation within $PH$	0.1159 (68.78%)	0.1132 (61.77%)