Mathematical Theory and Modeling
ISSN 2224-5804 (Paper) ISSN 2225-0522 (Online)
Vol.5, No.10, 2015

A stochastic Approach for Intergenerational Socioprofessional Mobility in France: A Markovian Analysis Applied to Data from "Formation et Qualification Professionnelle" Surveys

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Abstract
In France, studies on social mobility are based on data from Training and Professional Qualification (Formation et Qualification Professionnelle, FQP, in French) surveys conducted over several decades by the National Institute of Statistics and Economic Studies. While previous researches limited their statistical analyses of data from these surveys at descriptive level, ours introduces a stochastic model that helps to better apprehend the evolution of intergenerational mobility and social structure over time in France. Thus, using data from six (1953, 1970, 1977, 1985, 1993 and 2003) FQP surveys, our paper analyses, with a regular Markov chain, the evolution of intergenerational mobility and social structure in France during five decades in adopting the two following approaches:
a) The Individual Process: Analysis of intergenerational transition probabilities and the matrices of the mean first passage times in each state of the system;
b) The Collective Process: Examining the condition of reversibility of different matrices of exchange and comparison of permanent vectors (fixed or limits) obtained from the intergenerational transition matrices.
The outcomes show a significant change (with the decline of lower-class) in the social structure in this country over the time, while the social immobility remains high in the upper-class.
Key words: Regular Markov chains, social structure, transition probabilities, destiny, origin, permanent vectors

1. Introduction

During the 19th century, social heredity was mainly a result of an economic capital passed over to the new generation (Cuin, 1993). However, this is no longer the case since now the economic activity is more and more linked to the obtained degree. In other words, the sociologists' researches are now focused on the outcomes of education on social mobility. And in light of their findings, there was a consensus among the sociologists on the following points:
1) Education may be a means for an individual social mobility ascendant;
2) Individual successes should not hide the fact that equal opportunities cannot be taken for granted even with Education;
3) Furthermore, there is no equal opportunity for the young graduated on jobs market.

According to Deubel et al. (2008), studies on social mobility started in USA between the two World wars and these originally dealt with social stratification analyses. And in France, according to Cuin (1993), it was towards the end of 70s when the general social mobility phenomena were, for the first time, conceptualized and therefore led the researchers to design the models for empirical facts analysis.

In France, the National Institute of Statistics and Economic Studies (Institut national de la statistique et des études économiques, INSEE), for many decades now, has been conducting the so-called «Training and Professional Qualification Surveys » (INSEE, 2007). In these surveys, the respondents are requested to provide information on intergenerational social mobility. This means that each respondent will provide:
1) The correct socioprofessional category of his father at the time he was finishing his studies (graduation time);
2) His own professional category on the survey's date.

The data collected from all these surveys are used by many scholars to explore the evolution of intergenerational mobility and social structure over time in France.

In contrast to several previous studies (Thélot, 1982 and 2004; Deubel et al., 2008; Dupays, 2006; Weiss, 1986), which limited their statistical analyses of data from these surveys at descriptive level (calculation of social mobility parameters, structural mobility and net mobility), our paper deals with the social mobility issue in France by using Regular Markov chains theories. In other words, we do a comparative analysis for the following elements of regular Markov's chains (ergodic and irreducible) with data from 1953, 1970, 1977, 1985, 1993 and 2003 FQP surveys:
1) Intergenerational transition matrices;

2) Mean first passage matrix in each social state/category (social class);
3) Fixed vectors (equilibrium state).

The added value for this method (regular Markov's chains) in the FQP data analysis is essentially twofold:
a) Use of fixed vectors in analysis of social structure evolution in France during a period of 50 years covered by these six FQP surveys. This approach was not used in any of above-mentioned previous studies;
b) Provide a precise measure of social distances between different states (upper, middle and lower-classes) of social structure in France.

Although the FQP surveys' data are not perfect due to some random and coding erreours (Thélot, 1982), they do, however, enable us to have a good understanding, over time, of the intergenerational mobility and social structure evolutions in France, for employed men and aged 40 – 50 years, from 1953 to 2003.

2. Definitions of key concepts

A social mobility study uses several concepts that need to be clearly defined:
1) Social mobility: Change of position on a social scale. This change can affect a person during his/her life time and this is called intragenerational mobility; or this change can take place between two successive generations and it is called intergenerational mobility;
2) Structural mobility: This is a mobility due to the social structure transformation as a result of increased/decreased number in different socioprofessional categories. For example, using the 2003 FQP survey data, table 4.5, we find that the decreased number in the different socioprofessional categories is 1773000. In this case, the structural mobility is therefore 25% (1773000/7047000*100). According to Dupays (2006), the structural mobility is a result of a huge decrease in the number of Farmers, a decline in industrial employment, and an increase in wage earners and tertiary;
3) Gross mobility: Balance (in %) between the sample size and the total of people who didn't change the social position (immobile). With data from 2003 FQP survey, table 4.5, the gross mobility is 65% (7047000 – 2488000)/7047000*100. Here, 2488000 is the total number of immobiles (sons who still in the same socioprofessional categories as their fathers);
4) Net mobility (or circulation mobility): Balance between gross mobility and structural mobility. With data from 2003 FQP survey, table 4.5, the net mobility is 40% (65% - 25%);
5) Social heredity: No social position change between two generations and which is referred to as a social immobility. For example, using the 1993 FQP survey data, table 4.4, we notice that 48% (1199000/2518000*100) of manuals were also working as manuals;
6) Social mobility table: Table with double entry that compares social position (socioprofessional categories) of sons to that of their parents (fathers). The tables 4.3, 4.4 and 4.5 are the concret examples social mobility table;
7) Destinies' table: A social table that analyses the distribution of sons from each socioprofessional category in all socioprofessional categories. In other words, a destinies table help us to answer to this question: in which socioprofessional categories are now the sons of….? For example, the data from the 1985 FQP survey, table 3.3, show that 60% (177,949/297,726*100) of sons of senior professionals were also senior professionals. We should underscore the fact that a destinies table deals also with the intergenerational mobility;
8) Recruitments' table: This social mobility table traces back the origin (socioprofessional category of father) of all individuals (sons) in each of socioprofessional category at the time of survey. In this context, the recruitments' table enable us to answer to this key question: Where come from (fathers' socioprofessional categories) the sons currently occupying each of the different socioprofessional categories? In case of the 2003 FQP survey data, table 4.5, we can see that 88% (252000/285000*100) of farmers were also sons of farmers.

In addition to the definitions provided above, it is very important to recall the existing relationship between a destinies' table and recruitments' table: Both are the two components of a social mobility table. The first deals with the sons' social mobility, while the second trace back their social origins (fathers' socioprofessional categories).

3. Brief presentation of used model

3.1 The Markov chains

We are not conducting an in-depth analysis of Markov chains but just making a brief presentation of one type of Markov chains called Regular Markov chains that are applied in this paper to the social mobility in France over a period of five decades.

We recommend our readers the two books of Kemeny and Snell (1960) and de Cullmann (1975), for more details on Markov chains.

3.2 Definition

A (finite) Markov chain is a process with a finite number of states (s_n) in which the probability of being in a particular state at step n + 1 depends only on the state occupied at step n. To each couple of states (s_i, s_j) there is an associate probability p_{ij} that shows the direct passage of state s_i to state s_j. The sum of p_{ij} (with j from 1 to n) yields 1, and P= (p_{ij})nn is a stochastic matrix called matrix of transition probabilities or transition matrix.

3.3 Categories of transition probabilities

There are two types of transition probabilities:

1) The transition probabilities that do not dependent on time (age, period): In this case, the associate Markov chain is called homogeneous in time; and the transition probabilities are referred to as stationary (or constant). However, it is very important to mention that there is difference between stationary transition probabilities and stationary distribution, which is a particular case of matrix with elements being equal on all rows. Indeed, with P^n (with n tending to infinity), the transition matrix P always converges to a particular matrix whose rows are all equal. The details are provided in the section devoted to the Regular Markov chains;

2) The transition probabilities that dependent on time (age, period): The Markov chains are called non homogeneous in time.

3.4 Types of Markov chains with discret time

There are two types of Markov chains with discret time:

1) Absorbing Markov chains;

2) Regular Markov chains (ergodic and irreducible).

In our paper, only the second type of Markov chains (Regular Markov chains) will be used. A Markov chain P is called ergodic and irreducible if only if the series P^n (with n tending to infinity) converges to a matrix completely positive ($p_{ij} > 0$). In other words, any state j is reachable from any state i, or the states i and j are communicant.

3.5 Regular Markov chains (homogeneous)

3.5.1 Definition

A Markov chain (homogeneous) is called regular if only if it has fixed distribution that is independent from the initial state. The formula is written as follows:

$$\lim_{n\to\infty} P^{(n)} = P^*, \text{ with } P^* \text{ Independent of } P^{(0)}$$

P^* is a fixed (limit) distribution and therefore: $T^{(n)} = T^{(0)} * P^{(n)}$

With n tending to infinity, we do have:

$$T^* = \lim_{n\to\infty} T^{(0)} * P^{(n)}$$

The existence of T* (T* is a fixed or permanent vector) is a confirmation of the existence of P* for all $P^{(n)}$ when n tends to infinity. In other words:

$$T^* = T(0) * \lim_{n\to\infty} P^{(n)}$$

And since

$$\lim_{n\to\infty} P^{(n)} = P^*$$

Therefore T* = T(0) * P*, with P* being a fixed distribution. The Markov chains whose matrix $P^{(n)}$ has a fixed P* = [p_j*], with $p_j^* > 0$ (j = 0, 1…n, n+1), are called fully (strongly) ergodic.

Example 3.9 (Kemeny and Snell, 1960): P is a matrix of transition probabilities for a regular Markov chain.

R *N* *S*

$$P = \begin{array}{c} \\ R \\ N \\ S \end{array} \begin{array}{c} \begin{array}{ccc} R & N & S \end{array} \\ \begin{bmatrix} 1/2 & 1/4 & 1/4 \\ 1/2 & 0 & 1/2 \\ 1/4 & 1/4 & 1/2 \end{bmatrix} \end{array}$$

P is regular Markov chain since all P^n (with n tending to infinity), we have $p_{ij} > 0$, and also P has a fixed distribution.

3.5.2 Calculation of a fixed vector

This is to determine a vector α = α * P. This can be written as follows:

$$(\alpha_1\ \alpha_2\ \alpha_3) * \begin{bmatrix} 1/2 & 1/4 & 1/4 \\ 1/2 & 0 & 1/2 \\ 1/4 & 1/4 & 1/2 \end{bmatrix} = (\alpha_1\ \alpha_2\ \alpha_3) \tag{3.1}$$

And this leads us to the following system of equations:

$$\begin{cases} \alpha_1 = \frac{1}{2}\alpha_1 + \frac{1}{2}\alpha_2 + \frac{1}{4}\alpha_3 \\ \alpha_2 = \frac{1}{4}\alpha_1 + \frac{1}{4}\alpha_3 \\ \alpha_3 = \frac{1}{4}\alpha_1 + \frac{1}{2}\alpha_2 + \frac{1}{2}\alpha_3 \\ \alpha_1 + \alpha_2 + \alpha_3 = 1 \end{cases} \tag{3.2}$$

The unique solution to these equations is α = (2/5, 1/5, 2/5); and therefore α is permanent vector. And the unique fixed distribution is:

$$P^* = \begin{array}{c} \\ R \\ N \\ S \end{array} \begin{array}{c} \begin{array}{ccc} R & N & S \end{array} \\ \begin{bmatrix} 2/5 & 1/5 & 2/5 \\ 2/5 & 1/5 & 2/5 \\ 2/5 & 1/5 & 2/5 \end{bmatrix} \end{array}$$

The Markov chain represented by this P* matrix of transition probabilities is strongly ergodic.

3.5.3 Fundamental matrix

For any regular Markov chains, the Fundamental matrix has the following formula: Z = {I – (P – P*)}-1. The main characteristics of this matrix is that the sum of elements of each row equals to 1.

Using the same example 3.9, we have:

$$Z = 1/75 \begin{array}{c} \\ R \\ N \\ S \end{array} \begin{array}{c} \begin{array}{ccc} R & N & S \end{array} \\ \begin{bmatrix} 86 & 3 & -14 \\ 6 & 63 & 6 \\ -14 & 3 & 86 \end{bmatrix} \end{array}$$

3.5.4 Using the Fundamental Matrix for the Construction of the Mean First Passage Matrix (Mean First Passage Time in each state)

The Mean First Passage Matrix is constructed by using the fundamental matrix Z. Its formula (Kemeny and Snell, 1960) can be written:

M = (I – Z + E * Zdg) * B, where:
Z = Fundamental matrix;
I = Identity matrix with same dimensions as Z;
E = Unit matrix;
B = Diagonal matrix of inverse of elements of main diagonal of matrix P*;

Zdg = Diagonal matrix of Z.

Using the same example 3.9, we do have:

$$\text{With B} = \begin{bmatrix} 5/2 & 0 & 0 \\ 0 & 5 & 0 \\ 0 & 0 & 5/2 \end{bmatrix}$$

$$\text{M} = \begin{array}{c} \\ R \\ N \\ S \end{array} \begin{array}{c} \begin{array}{ccc} R & N & S \end{array} \\ \begin{bmatrix} 5/2 & 4 & 10/3 \\ 8/3 & 5 & 8/5 \\ 10/3 & 4 & 5/2 \end{bmatrix} \end{array}$$

The matrix M provides the mean first passage time from a state i to a state j. Hence, if we are in state N, it will respectively take us 8/3, 5 and 8/5 time units (for example, days, months, years, generations, etc.) to reach the states R, N and S.

4. Application of Markov chains to data from FQP surveys

4.1 Some comments on results (destinies and recruitments) from 1953, 1970 and 977 FQP surveys

Table 4.1: Destinies according to three social groups (sons: working men aged 40 to 59 years)

Father's social position	**Son's social position**				
	Year	**Upper-class**	**Middle-class**	**Lower-class**	**Total**
Upper-class	1953	51	34	15	100
	1970	51	34	15	100
	1977	50	35	15	100
Middle-class	1953	10	56	34	100
	1970	18	47	35	100
	1977	21	45	34	100
Lower-class	1953	2	22	76	100
	1970	5	25	70	100
	1977	6	25	69	100
Total	1953	6	31	63	100
	1970	12	31	57	100
	1977	14	32	54	100

Sources: Th dot (1982) and Th dot (2004)

The results show a social quasi-stability between 1953 and 1977. The only changes noticed are the following: the proportion of sons from middle-class decreases from 56% in 1953 to 45% in 1973, and proportion of sons from upper-class increases from 10% in 1953 to 21%; while the proportion of sons from lower-class who moved to upper-class increases from 2% in 1953 to 6% to in 1973. In the social structure, the percentage of the upper-class increases from 6% in 1953 to à 14% in 1973, while that of lower-class decreases from 63% in 1953 to 54% in 1973.

Table 4.2: Recruitment (origin) according to three social groups (sons: working men aged 40 to 59 years)

Father's social position	Son's social position				
	Year	Upper-class	Middle-class	Lower-class	Total
Upper-class	1953	40	5	1	5
	1970	32	8	2	7
	1977	29	9	2	8
Middle-class	1953	42	44	13	24
	1970	42	40	16	27
	1977	42	39	17	27
Lower-class	1953	18	51	86	71
	1970	26	52	82	66
	1977	29	52	81	65
Total	1953	100	100	100	100
	1970	100	100	100	100
	1977	100	100	100	100

Sources: Thélot (1982) and Thélot (2004).

The same quasi-stability situation is also observed in the recruitment (origin) results during the period of 1953 to 1977. Few changes noticed are as follows: proportion of sons from upper-class decreases from 40% to 29%, while that of sons from lower-class increases from 18% to 29%.

4.2 Presentation of raw data from 1985, 1993 and 2003 FQP surveys

Somme of the raw data from these three surveys have been used in the examples provided in section of definition of key concepts, chapter 3 of this paper.

Table 4.3: Socioprofessional groups (or last active group) according to that of father (sons: active or former active men aged 40 to 59 years, 1985 FQP survey)

Father's Socioprofessional group	Son's Socioprofessional groups							
	Farmers	Businesmen (Small size)	Senior level professions	Intermediat Professions	Employees.	No-farm workers	Farm workers	Total
Farmers	381693	99029	56845	134964	76196	233121	146275	1128123
Businesmen (Small size)	15788	233697	157746	155019	57965	143059	42591	805865
Senior level professions	1416	27431	177949	61738	17765	7275	4152	297726
Intermediat professions	527	45043	143992	141387	40030	65786	15570	452335
Employees	1416	43756	102688	142409	62713	78127	18712	449821
No-farm workers	18642	152463	129549	358789	159021	555932	183740	1558136
Farm workers	6629	22900	6921	32515	23232	76639	55478	224314
Unknown	1976	19806	13504	33458	24160	67395	37111	197410
Total	428087	644125	789194	1060279	461082	1227334	503629	5113730

Source: Gollac et al. (1988)

Table 4.4: Socioprofessional group of son according to that of father (sons: active or former active men aged 40 to 59 years in 1993, figures in thousands)

Father's Socioprofessional group	**Son's Socioprofessional group**						
	Farmers	**Artisans, Businessmen and CEOs**	**Senior level professions**	**Intermediat professions**	**Employees**	**Manual**	**Total**
Farmers	260	88	108	166	95	520	1237
Artisans, Businessmen and CEOs	14	257	180	179	62	204	896
Senior level professions	4	57	276	108	42	36	523
Intermediat professions	5	64	227	196	61	99	652
Employees	1	55	152	224	75	196	703
Manual	22	224	234	580	259	1199	2518
Total	306	745	1177	1453	594	2254	6529

Source: Dupays (2006).

Table 4.5: Socioprofessional category of son according to that of father (sons: active men or former active aged 40 to 59 years in 2003, figures in thousands)

Father's profession and social category	**Son's profession and social category**						
	Farmers	**Artisans, Businessmen and CEOs**	**Senior level professions**	**Intermediat professions**	**Employees**	**Manual**	**Total**
Farmers	252	72	105	190	98	426	1 143
Artisans, Businessmen and CEOs	6	182	189	205	79	210	871
Senior level professions	2	37	310	152	37	52	590
Intermediat professions	2	60	266	263	73	135	799
Employees	3	43	144	179	108	169	646
Manual	20	225	304	701	375	1373	2998
Total	285	619	1318	1690	770	2365	7047

Sources: Deubel et al. (2008) & Dupays (2006)

4.3 Grouping the raw data into three social classes and matrices of transition probabilities for the FQP surveys 1985, 1993 and 2003

With respect to the 1985, 197,410 FQP surveys, people who were unable to trace back their fathers' socioprofessional categories were excluded from the target population (5113730). The assumption made here is

that the erreours (no reponse) were not randomly (proportionally) distributed within the target population (Merlliéet Prévot, 1991). And as a result, the population size used for the study is 4916320 people.

We should bear in mind that the data grouping into three social classes was done based on criteria set by Thélot (1982), with all limitations/criticisms that may be raised on this issue. However, Thélot put forward the convenience aspects/reasons and we do agree with: Two people can belong to two different socioprofessional categories (but close) and be at same time in the same social class.

Table 4.6: 1985 FQP survey data regrouped into three social classes

Father's social position	**Son's social position**			
	Upper-Class	**Middle-Class**	**Middle-Class**	**Total**
Upper-Class	177949	106934	12843	297726
Middle-Class	404426	922,019	361576	1708021
Lower-Class	193315	1059109	1658149	2910573
Total	775690	2088062	2052568	4916320

The component of each of the three social classes are as follows:
Upper-Class = Senior Managers;
Middle-Class = Intermediate professions + Businessmen + Employees
Lower-Class = Manual + Farmers

From the table 4.6, we come up with an intergenerational transition matrix T, as well as the table 4.7 that summarizes the respondents' social origins.
The intergenerational transition matrix (T), 1985 FQP survey is:

$$T = \begin{array}{c} \\ D \\ M \\ P \end{array} \begin{array}{c} \begin{array}{ccc} D & M & P \end{array} \\ \begin{bmatrix} 0.60 & 0.36 & 0.04 \\ 0.24 & 0.54 & 0.22 \\ 0.07 & 0.36 & 0.57 \end{bmatrix} \end{array}$$

On this matrix T, we observe on the main diagonal a high level of social immobility in the all three classes with 60% in upper-class, 54% in middle-class and 57% in lower-class. At same time, the lowest social mobility is noticed between upper and lower classes, with 4% from upper-class to lower-class and 7% from lower-class to upper-class.

Table 4.7: Origin (recruitment) of sons, 1985 FQP survey

Origin	**Upper-Class**	**Middle-Class**	**Middle-Class**	**Total**
Upper-Class	0.23	0.05	0.01	0.06
Middle-Class	0.52	0.44	0.18	0.35
Lower-Class	0.25	0.51	0.81	0.59
Total	1	1	1	1

This table 4.7 shows that the upper-class is made up of 23% of sons from the same social class while 52% and 25% are respectively from middle and lower-classes. Very few sons from upper-class have moved into the middle-class (5%) and lower-class (1%). Sons from lower-class are majority in the same social class (81%) and in middle-class (51%). Overall, majority (59%) of the respondents are sons from lower-class.

Table 4.8: 1993 FQP survey data regrouped in three social classes

Father's social position	Son's social position			
	Upper-Class	Middle-Class	Middle-Class	Total
Upper-Class	276	207	40	523
Middle-Class	559	1173	519	2251
Lower-Class	342	1412	2001	3,755
Total	1177	2792	2560	6529

From this table 4.8, we come up with the intergenerational transition matrix T, as well as the table 3.9 summarizing the social class origins of respondents.

The intergenerational transition matrix T, 1993 FQP survey, is:

$$T = \begin{array}{c} \\ D \\ M \\ P \end{array} \begin{array}{c} \begin{array}{ccc} D & M & P \end{array} \\ \begin{bmatrix} 0.53 & 0.39 & 0.08 \\ 0.25 & 0.52 & 0.23 \\ 0.09 & 0.38 & 0.53 \end{bmatrix} \end{array}$$

While the social immobility stands at 53% for all three social classes, the social mobility between upper-class and lower-class is however very low (from 8 to 9%).

Table 4.9: Origin (recruitment) of sons, 1993 FQP survey

Origin	Upper-Class	Middle-Class	Middle-Class	Total
Upper-Class	0.23	0.07	0.02	0.08
Middle-Class	0.48	0.42	0.20	0.34
Lower-Class	0.29	0.51	0.78	0.58
Total	1	1	1	1

From this table 4.9, three elements can be highlighted. The first one is that the upper and middle-classes are mostly made up respectively of 48% of sons from middle-class and 51% of sons from lower-class. The second one is that deals with the low level of representation of sons from upper-class in middle-class (7%) and low-class (2%). The third one is that in total, the sons from lower-class are majority with 58%.

Table 4. 10: Regrouping 2003 FQP survey data in three social classes

Father's social position	Son's social position			
	Upper-Class	Middle-Class	Middle-Class	Total
Upper-Class	310	226	54	590
Middle-Class	599	1192	525	2316
Lower-Class	409	1,661	2071	4141
Total	1318	3079	2650	7047

From this table 4.10, an intergenerational transition matrix T, and the table 4.11 summarizing the social origins of respondents, are deduced.

Intergenerational transition matrix (T), 2003 FQP survey:

$$T = \begin{array}{c} \\ D \\ M \\ P \end{array} \begin{array}{c} \begin{array}{ccc} D & M & P \end{array} \\ \begin{bmatrix} 0.53 & 0.38 & 0.09 \\ 0.26 & 0.51 & 0.23 \\ 0.10 & 0.40 & 0.50 \end{bmatrix} \end{array}$$

This matrix (T) almost has the same characteristics as the ones observed in the 1993 FQP survey data: low social mobility (varies from 9% to 10%) between, on one hand upper-class and lower-class, and on other hand the social immobility (50% to 53%) in the three social classes.

Table 4.11: Origin (recruitment) of sons, 2003 FQP survey

Origin	**Upper-Class**	**Middle-Class**	**Middle-Class**	**Total**
Upper-Class	0.24	0.07	0.02	0.08
Middle-Class	0.45	0.39	0.20	0.33
Lower-Class	0.31	0.54	0.78	0.59
Total	1	1	1	1

The table 4.10 has similar characteristics to that noticed in table 4.9, and therefore the three observations also apply to this table 4.10:

- Upper and middle-classes are mostly made up respectively of 45% of sons from middle-class and 54% of sons from lower-class;
- Low level of representation of sons from upper-class in middle-class (7%) and low-class (2%); and
- In total, the sons form lower-class are majority with 59%.

4.4 Summary tables of destinies and recruitments for all six (1953, 1970, 1977, 1985, 1993 and 2003) FQP surveys

By inserting the destinies and recruitments of the three 1985, 1993 and 2003 FQP surveys, respectively into the tables 4.1 and 4.2, we obtain, respectively, the tableaux 4.12 and 4.13.
Keep in mind that the different parameters regrouped in these two new tables have already been analyzed in previous pages but we will deal with them again with more details in the sub-section 4.6.1 devoted to the individual process.

Table 4.12: Destiny according to social groups (sons: working men aged 40 to 59 years)

Father's social position	**Son's social position**				
	Year	**Upper-Class**	**Middle-Class**	**Lower-Class**	**Total**
Upper-Class	1953	51	34	15	100
	1970	51	34	15	100
	1977	50	35	15	100
	1985	60	36	4	100
	1993	53	39	8	100
	2003	53	38	9	100
Middle-Class	1953	10	56	34	100
	1970	18	47	35	100
	1977	21	45	34	100
	1985	24	54	22	100
	1993	25	52	23	100
	2003	26	33	41	100
Lower-Class	1953	2	22	76	100
	1970	5	25	70	100
	1977	6	25	69	100
	1985	7	36	57	100
	1993	9	38	53	100
	2003	10	40	50	100
Total	1953	6	31	63	100
	1970	12	31	57	100
	1985	14	32	54	100
	1977	16	42	42	100
	1993	18	43	39	100
	2003	19	44	37	100

This table 4.12, regroups the destinies (intergenerational transition matrices) and the social structure for the six FQP surveys.

Table 4.13: Origin according to social groups (sons: working men aged 40 to 59 years) for all six FQP surveys

Father's social position	Son's social position				
	Year	Upper-Class	Middle-Class	Lower-Class	Total
Upper-Class	1953	40	5	1	5
	1970	32	8	2	7
	1977	29	9	2	8
	1985	23	5	1	6
	1993	23	7	2	8
	2003	24	8	2	8
Middle-Class	1953	42	44	13	24
	1970	42	40	16	27
	1977	42	39	17	27
	1985	52	44	18	35
	1993	48	42	20	34
	2003	45	29	20	33
Lower-Class	1953	18	51	86	71
	1970	26	52	82	66
	1977	29	52	81	65
	1985	25	51	81	59
	1993	29	51	78	58
	2003	31	63	78	59
Total	1953	100	100	100	100
	1970	100	100	100	100
	1977	100	100	100	100
	1985	100	100	100	100
	1993	100	100	100	100
	2003	100	100	100	100

In addition to the recruitment's results for the six FQP surveys, the tableau 4.13 regroups (last column) the demographic weights of each three social classes in the total.

4.5 Calculation of equilibrium state's parameters of regular Markov chains for the six FQP surveys

4.5.1 Calculation of fixed/permanent vectors

Example, 1953:

$$(x,\ y,\ 1\text{-}x\text{-}y)\ *\ \begin{bmatrix} 0.51 & 0.34 & 0.15 \\ 0.10 & 0.56 & 0.34 \\ 0.02 & 0.22 & 0.76 \end{bmatrix} = (x,\ y,\ 1\text{-}x\text{-}y) \qquad (4.1)$$

This leads us to the following equations system:

$$\begin{cases} x = 0.51x + 0.10y + 0.02(1-x-y) \\ y = 0.34x + 0.56y + 0.22(1-x-y) \\ 1-x-y = 0.15x + 0.34y + 0.76(1-x-y) \end{cases} \qquad (4.2)$$

The unique solution is that x = 0.09 and y = 0.35. The permanent vector is therefore: (0.09 0.35 0.56).

Using the same procedure for 1970, 1977, 1985, 1993 and 2003 FQP surveys, we obtain respectively the following permanent vectors: (0.18 0.34 0.48); (0.20 0.34 0.46); (0.31 0.44 0.25); (0.29 0.44 0.27) and (0.30 0.44 0.26).

4.5.2 Mean First Passage Matrices (mean number of necessary generations for the first passage/stay in each social class)

The N matrices are constructed by using the formula proposed by Kemeny and Snell (1960, P.79). The obtained results are as follows:

1) Matrix of mean number of necessary generations to go from one social class (D, M, P) to another, 1953 FQP survey:

$$N = \begin{array}{c} \\ D \\ M \\ P \end{array} \begin{array}{c} \begin{array}{ccc} D & M & P \end{array} \\ \begin{bmatrix} 11 & 6 & 6 \\ 30 & 3 & 5 \\ 35 & 6 & 2 \end{bmatrix} \end{array}$$

2) Matrix of mean number of necessary generations to go from one social class (D, M, P) to another, 1970 FQP survey:

$$N = \begin{array}{c} \\ D \\ M \\ P \end{array} \begin{array}{c} \begin{array}{ccc} D & M & P \end{array} \\ \begin{bmatrix} 6 & 6 & 7 \\ 14 & 3 & 6 \\ 16 & 7 & 2 \end{bmatrix} \end{array}$$

3) Matrix of mean number of necessary generations to go from one social class (D, M, P) to another, 1977 FQP survey:

$$N = \begin{array}{c} \\ D \\ M \\ P \end{array} \begin{array}{c} \begin{array}{ccc} D & M & P \end{array} \\ \begin{bmatrix} 5 & 6 & 7 \\ 13 & 3 & 6 \\ 14 & 7 & 2 \end{bmatrix} \end{array}$$

4) Matrix of mean number of necessary generations to go from one social class (D, M, P) to another, 1985 FQP survey:

$$N = \begin{array}{c} \\ D \\ M \\ P \end{array} \begin{array}{c} \begin{array}{ccc} D & M & P \end{array} \\ \begin{bmatrix} 3 & 5 & 13 \\ 9 & 2 & 11 \\ 10 & 5 & 4 \end{bmatrix} \end{array}$$

5) Matrix of mean number of necessary generations to go from one social class (D, M, P) to another, 1993 FQP survey:

$$N = \begin{array}{c} \\ D \\ M \\ P \end{array} \begin{array}{c} \begin{array}{ccc} D & M & P \end{array} \\ \begin{bmatrix} 3 & 3 & 7 \\ 5 & 2 & 6 \\ 6 & 3 & 4 \end{bmatrix} \end{array}$$

6) Matrix of mean number of necessary generations to go from one social class (D, M, P) to another, 2003 FQP survey:

$$N = \begin{array}{c} \\ D \\ M \\ P \end{array} \begin{array}{c} \begin{array}{ccc} D & M & P \end{array} \\ \begin{bmatrix} 3 & 3 & 7 \\ 5 & 2 & 6 \\ 6 & 3 & 4 \end{bmatrix} \end{array}$$

4.5.3 Exchange matrices

With the formula B-1* T, we can construct the so-called exchange matrix between states (three social classes upper, middle and lower) of a system. This matrix, as already mentioned in part 2, allows the verification of the reversibility condition (equilibrium sate). The obtained results for the six FQP surveys are as follows:

1) Exchange matrix, 1953 FQP survey:

$$B^{-1} * T = \begin{array}{c} \\ D \\ M \\ P \end{array} \begin{array}{c} \begin{array}{ccc} D & M & P \end{array} \\ \begin{bmatrix} 0.046 & 0.031 & 0.014 \\ 0.035 & 0.196 & 0.119 \\ 0.011 & 0.123 & 0.426 \end{bmatrix} \end{array}$$

2) Exchange matrix, 1970 FQP Survey:

$$B^{-1} * T = \begin{array}{c} \\ D \\ M \\ P \end{array} \begin{array}{c} \begin{array}{ccc} D & M & P \end{array} \\ \begin{bmatrix} 0.092 & 0.061 & 0.027 \\ 0.061 & 0.160 & 0.119 \\ 0.024 & 0.120 & 0.336 \end{bmatrix} \end{array}$$

3) Exchange matrix, 1977 FQP survey:

$$B^{-1} * T = \begin{array}{c} \\ D \\ M \\ P \end{array} \begin{array}{c} \begin{array}{ccc} D & M & P \end{array} \\ \begin{bmatrix} 0.100 & 0.070 & 0.030 \\ 0.071 & 0.153 & 0.116 \\ 0.028 & 0.115 & 0.317 \end{bmatrix} \end{array}$$

4) Exchange matrix, 1985 FQP survey:

$$B^{-1} * T = \begin{array}{c} \\ D \\ M \\ P \end{array} \begin{array}{c} \begin{array}{ccc} D & M & P \end{array} \\ \begin{bmatrix} 0.186 & 0.112 & 0.012 \\ 0.106 & 0.238 & 0.097 \\ 0.018 & 0.090 & 0.143 \end{bmatrix} \end{array}$$

5) Exchange matrix, 1993 FQP survey:

$$B^{-1} * T = \begin{array}{c} \\ D \\ M \\ P \end{array} \begin{array}{c} \begin{array}{ccc} D & M & P \end{array} \\ \begin{bmatrix} 0.154 & 0.113 & 0.023 \\ 0.110 & 0.229 & 0.101 \\ 0.024 & 0.103 & 0.143 \end{bmatrix} \end{array}$$

6) Exchange matrix, 2003 FQP survey:

$$B^{-1} * T = \begin{array}{c} \\ D \\ M \\ P \end{array} \begin{array}{c} \begin{array}{ccc} D & M & P \end{array} \\ \begin{bmatrix} 0.159 & 0.114 & 0.027 \\ 0.114 & 0.224 & 0.101 \\ 0.026 & 0.104 & 0.130 \end{bmatrix} \end{array}$$

4.6 Lesson learned and Fidings

With a transition matrix of a Regular Markov chain (ergodic and irreducible), as it is the case in our paper, we can conduct two types of analyses (Kemeny and Snell, 1960: 191). The first one deals with the intergenerational transition probabilities and the mean first passage matrix (mean number of necessary generations for the first passage/stay in each social class). This approach is called «Individual Process ».

The second type of analysis is that, by using the intergenerational transition probabilities, tries to predict the distribution of target (under study) population in the different states of a system at equilibrium state. This is what is referred to as a «Collective Process », which involves the verification of exchange matrix reversibility condition as well as the calculation of the fixed/permanent vector or the stationary distribution.

4.6.1 Individual Process

For the 1953, 1970 and 1977 FQP surveys, Thélot (1982) used one part of the first approach to analyze the evolution of intergenerational social mobility in France between the three dates. The conclusion reached is that there was a quasi-stability in social class destinies and origins (recruitment) from 1953 to 1977, as shown in the tables 4.1 and 4.2. The only significant changes recorded from 1953 to 1977 are as follows:
i) Destiny : The proportion of sons from middle-class decreases from 56% to 45% in the same social class, and that of sons from upper-class increases from 10% to 21% in same social class; while that of sons from lower-class slightly increases from 2% to 6% in upper-class;
ii) Recruitment: The proportion of sons from upper-classer decreases from 40% to 29% in the same social class, while that of sons from lower-class increases from18% to 29% in upper-class;
iii) Social structure: The proportion of upper-class increases from 6% to 14%, while that of lower-class decreases from 63% to 54%. In other words, the increase of upper-class proportion is mainly due to the continuous decline of lower-class proportion.

Comparing the results from the 1977 and 1985 FQP surveys, we do observe the following changes:
i) Destiny : The proportion of sons from upper-class and who still in the same social class increases from 50% in 1977 to 60% in 1985, while that of sons in the lower-class decreases from 15% to 4%. The proportion of sons from middle-class and who remain in the social class during the two surveys increases from 45% to 54%, while that of those in the lower-class decreases from 34% to 22%. The proportion of sons from lower-class and who still in the same social class decreases from 69% to 57%, while that of those who are in the middle-class increases from 25% to 36%;
ii) Recruitment: The proportion of sons from middle-class and who are in the upper-class increases from 42% to 52%. In other words, there is a great determination for sons from middle-class to go for the higher level in the social structure;
iii) Social structure: The progressive decline of proportion (from 54% to 42%) of lower-class is here confirmed but this time around it is hugely benefiting to the middle-class with an increase from 32% to 42%.

From 1985 to 2003, the following changes are observed:
i) Destiny: The proportion of sons from upper-class and who still in the same social class decreases from 60% to 53%, while that of those from lower-class increases slightly from 4% to 9%. At the same time, the proportion of sons from middle-class and who remain in the same group decreases slightly 54% to 51%. Also, the proportion of sons from lower-class and who occupy the same category decreases from 57% to 50%; while that of those in middle-class increases slightly from 36% to 40%, and that of those in upper-class slightly decreases from 7% to 10%;
ii) Recruitment: The proportion of sons from middle-class who are in upper-class decreases from 52% to 45%, and this decline is mainly benefiting to the sons from lower-class whose percentage increases from 25% to 31% in upper-class. For the sons from middle-class, the proportion of immobile decreases from 44% to 39%, while that of those in lower-class slightly increases from 51% to 54%. In lower-class, proportion of immobile slightly decreases from 81% to 78%;

iii) Social structure: Here again is a confirmation of the ongoing decline (from 42% to 37%) of lower-class and which is benefiting to the upper and middle-classes.

It is very important to recaIl that the simple comparison of different proportions (columns 3, 4 and 5 of table 4.2) that represent the demographic weight of each social class in the social structure for the first three FQP surveys is not the appropriate way to measure the evolution in social structure over time. The reason is simple (obvious): those proportions are not at the equilibrium state and therefore they cannot measure the real changes that took place over time in the social structure. In this context, the fixed vectors are the appropriate parameters that allow a better measurement of evolution in the social structure over time.

Another interesting tool in the Individual Process is the mean first passage matrix in each state (social class). This matrix provides the number of necessary generations to go from one social class to another. The elements on the main diagonal of the mean first passage matrix show in particular the number of the required steps (transitions or generations) to comeback in the same state once we leave it.

However, in this kind of research it is advised not be more focused on the different mean numbers generated by the mean first passage matrices. What is more and more important to be considered is the comparison of relative/proportional social class distances between two communicant states i and j. Here, we have to determine between the two states i and j, which one is more socially close to another. In other words, wich one of the two states i and j takes less time to change the social class. Thus, for example, between the upper-class and the other two (middle and lower-classes), the following are observed:
i) In 1953: Sons from lower-class almost need six times (35 divide by 6) to go to upper-class than that of the sons from the latter social class to go to lower-class. The sons from the middle-class almost need 5 times to go to upper-class;
ii) In 1970 and 1977: The social distance between on one hand the upper-class and on other hand the middle and lower-classes, has been divided by two;
iii) In 1985: The sons from middle-class need 1.8 more times to go to upper-class than the sons from the latter to go on opposite direction. Between lower and upper-classes, the proportional social distance is 0.8 time, while that between lower and middle-classes is 0.5 (5 divide by 11). These two relative social distances inferior to 1 show a very low descendant social mobility respectively from upper and middle-classes to the lower-class;
iv) In 1993 and 2003: The sons from middle-class need 1.7 more times to go to upper-class than the sons from the latter to go on opposite direction. The passage of sons from lower-class to upper and middle-classes requires respectively 0.9 and 0.5 more times. These two proportional social distances inferior to 1 is a confirmation of the trend observed from 1985. In other words, a very low descendant social mobility from respectively upper and middle-classes to the lower-class.

4.6.2 Collective Process

Before proceeding with the fixed vectors analysis, it is important that we examine the condition of reversibity for the different intergenerational transition matrices T. In this context, we have to verify if there is a fair exchange between the different states (social classes) of the system under consideration in our paper. Actually, this means that a test is needed to make sure that the fixed vector found is the unique solution or the stationary distribution. Hence, we have to verify if all exchange matrices (B-1 * T) are symmetric (or almost symetric). All our results (exchange matrices) meet this criterion.

The long-run trend observed, by examining the six fixed vectors associate to the intergenerational transitions probabilities matrices constructed with data from the six FQP surveys, is that the proportion of the lower-class continues to decline in the social structure from 1953. This was already highlighted in the Individual Process, and several elements explain this phenomenon. We can mainly mention the following: economic development, population ageing for manual and farmers, increase of women participation on job market, high level of education reached (possibility social capillarity) by the sons from lower-class, and international migration.

As we have already mentioned it the Individual Process, the comparison of the different fixed vectors (equilibrium state) seems to be the best way to measure the evolution in the social structure over time.

An in-depth analysis of evolution in social structure in France, conducted with data from the six FQP surveys, led us to the identification of a trend with three phases at equilibrium state. The first phase, that deals with the comparison of three fixed vectors related to the 1953, 1970 and 1977 FQP surveys data, shows a significant changes in the proportions of upper-class (increasing from 9% in 1953 to 20% in 1997) and lower-class (progressive decline from 56% in 1953 to 46% in 1977), while those of middle-class remain stable at around

34% during the same period. The main explaination for this social phenomenon is a combination of economic development and ascendent mobility for the lower-class.

With respect to the second phase, the comparison of the two fixed vectors related to the data from the 1977 and 1985 FQP surveys shows a significant evolution in the social structure between the two dates: a sharp decline (from 46% to 25%) in the proportions of the lower-class, while those of upper and middle-classes have respectively increased of 11% and 10%. Once again, the evolution in the social structure is mainly due to the development of tertiary activities (Dupays, 2006).

The third phase deals with the comparison of three fixed vectors obtained with data from 1985, 1993 and 2003 FQP surveys. This phase is characterized by a quasi-stability in the social structure: The proportions of middle-class remain at 44%, those of lower-class slightly increase from 25% to 26%, while those of upper-class slightly decrease from 31% to 30%.

In terms of gains made during the three phases of evolution in the social structure in France, the results show that the upper-class was better off. Some elements explain better this situation at equilibrium state: Economic development, high social immobility in upper-class, high ascendent social mobility for lower-class, and low descendent social mobility as well as social immobility for middle-class. Briefly, all these changes played a major in the decline of proportion of the lower-class in the social structure in France.

5. Conclusion

An in-depth analysis of intergenerational mobility and social structure evolution over time requires the use of the two processes: Individual and Collective processes. The first one analyses the trend of intergenerational transition matrices, and the mean first passage time matrices. The second one tries to predict, using intergenerational transition matrices, the distribution of the targeted population in the different states of the system at equilibrium state, with the calculation of the fixed vectors.

As was the case with the methods used in the FQP surveys data analysis in previous studies, the main limitations noticed with the Markov chains are those related to the data quality. The three following important element are to be undescored:
1) Thélot (1982) states that the data from the 1953, 1970 and 1977 FQP surveys are not perfect due to some random and coding errors;
2) Thélot (2004) recognizes that the grouping of data into three social classes (Upper-class, middle-class and lower-class) may be challengeable;
3) The characteristics of the targeted population by the six FQP surveys: Active and employed men aged 40 to 59 years. In other words, only sons in this age-group and also active and employed are concerned. The objective of these FQP surveys is to identify the Father's and son's socioprofessional category during their active lives.

Despite the limitations described above, the use of Regular Markov chain in the FQP surveys data analysis allow us to better apprehend the evolution of intergenerational mobility and social structure in France, from 1953 to 2003.

Looking at the different previous studies (Thélot, 1982 et 2004; Deubel et al., 2008; Dupays, 2006 ; Weiss, 1986) devoted to the data analysis of the FQP surveys in France, it is noted that all researchers used one part (calculation of proportions for social and structural mobilities, and net mobility) of Individual Process. However, as well detailed above, the findings seem to be incomplete due to the fact that the parameters used in analysis of the social structure evolution are not at equilibrium state. In this context, our paper is trying to bring in a modest contribution by using the two processes in the data analysis of the six FQP surveys conducted in France by the National Institute of Statistics and Economic Studies.

The long-run trend observed from our findings is that the social structure in France has experienced a significant evolution over the five decades under consideration. If the lower-class decline can largely be attributed to the economic development, population ageing for manual and farmers, increase of women participation on job market, high level of education reached (possibility social capillarity) by the sons from lower-class, rural exodus and international migration, the gains made by the middle and upper classes are a result of a social capillarity in chain, and high social immobility in the upper-class.

Based on the obtained results, when compared to those from the previous researches, the stochastic model used in our paper proves to be a suitable approach for a comprehensive study on social mobility. Also, the high level

of social immobility observed in the upper-class actually reflects persistent unequal opportunities during the five decades covered by the six FQP surveys; and therefore the future researches on social mobility in France should explore the determinants of this major social issue.

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