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# *WHEN SMALLER FAMILIES LOOK CONTAGIOUS:*

## *A SPATIAL LOOK AT THE FRENCH FERTILITY DECLINE USING AN AGENT-BASED SIMULATION MODEL*

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# *When Smaller Families Look Contagious: A Spatial Look at the French Fertility Decline Using an Agent-based Simulation Model*

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## Abstract

Despite some disagreements about specific timing, it is now widely accepted that France was the first European country to experience a systematic decline in fertility, a decline that took place in a very distinctive geographical pattern. Whereas two areas of low birth rates (the Seine valley and the Aquitaine region) kept spreading, two 'islands' of high fertility (Bretagne and the Massif Central) shrank until they more or less disappeared in the early 1900s. In an attempt to provide a sensible explanation of this pattern, we build an agent-based simulation model which incorporates both historical data on population characteristics and spatial information on the geography of France, and allows us to study the role of social influence in fertility decisions. We assess how different behavioural assumptions and network topologies cause variations in diffusion patterns, using quantitative data on the Ecclesiastical Oath of 1791 to proxy for the impact the Revolution. Analysis of several simulations shows that a combination of both endogenous and exogenous factors help to explain the way in which the diffusion took place and suggests some of the mechanisms through which this was materialised.

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| **Keywords** | Economic history, demographic history (Europe pre-1913), France, demographic economics, fertility, simulation models (agent-based), diffusion. |
| **JEL classification** | N33, J13, C15. |

# 1. Introduction

France was the first country in Europe to experience a systematic fall in birth rates in the nineteenth century, but at least two further features make the French fertility decline particularly noteworthy: how long it took and how persistent internal heterogeneity was throughout. The uneven development of fertility rates took place in a quite distinctive geographical pattern, where two clear areas of low fertility (the Seine valley and the Aquitaine region) appeared to spread their influence while two 'islands' of high fertility (Bretagne and the Massif Central) kept shrinking until they more or less disappeared in the early 1900s. Standard quantitative analyses have shed light on some of the factors driving this dynamic [e.g. Weir, 1983; Wrigley, 1985; Murphy, 2008], but to better understand the mechanisms underlying this apparent diffusion, we need other tools. In an attempt to advance the understanding of this salient feature of the French fertility decline, we present an agent-based simulation model which incorporates both historical data on population characteristics and spatial information on the geography of France, and assesses how different behavioural assumptions regarding social interaction might have affected variations in the patterns followed by fertility rates.[1]

The model incorporates two components normally neglected in the literature. On the one hand, we introduce the role of social influence in fertility decisions, as hinted by recent studies [e.g. Kohler, 2001]. Whatever their desired family size, couples do not want their actual family size to be too far from that of their neighbours, and they will look to them when deciding on the number of children to have. This sets up an endogenous process of social interaction that we investigate by introducing different assumptions on the strength of this influence. We also bring in the effect of the French Revolution. The simultaneity of the onset of the decline with the events that took place from the summer of 1789 is quite suggestive already, but an increasing literature is now pointing towards a more regular connection between social upheavals and fertility decline [Binion, 2001; Caldwell, 2004; Bailey, 2006]. We build upon these studies and introduce the Revolution in the model as a heterogeneous, exogenous shock to the population. Individuals in more 'progressive' *départements* are more likely to be affected by a shock making them want to have fewer children, and we use *département* level quantitative data on the Ecclesiastical Oath of loyalty to the Revolution of 1791 [see Tackett, 1986] to proxy for the percentage of agents switching to this new status. Here the (not entirely implausible) assumption we make is that the proportion of priests swearing the Oath might somehow reflect the proportion of the population adhering to more modern or secular attitudes, or to the general ideas or policies of the Revolution. For the sake of simplicity, the model takes as exogenous the maximisation process carried out by individuals when deciding their fertility rates. This is not a costless stylisation, as the factors driving the decline could be important in understanding the dynamics, but the extensive literature on these factors [e.g. van de Walle, 1976; Flandrin, 1979; Weir, 1983; Murphy, 2008] allow us to hypothesise about them while the simplicity of the model we propose here lets us study factors normally ne-

[1] In this sense, the paper connects with the literature that instead of focusing on *why* there was a fertility decline it is more concerned with *how* it took place [e.g. Bocquet-Appel and Jakobi, 1998].

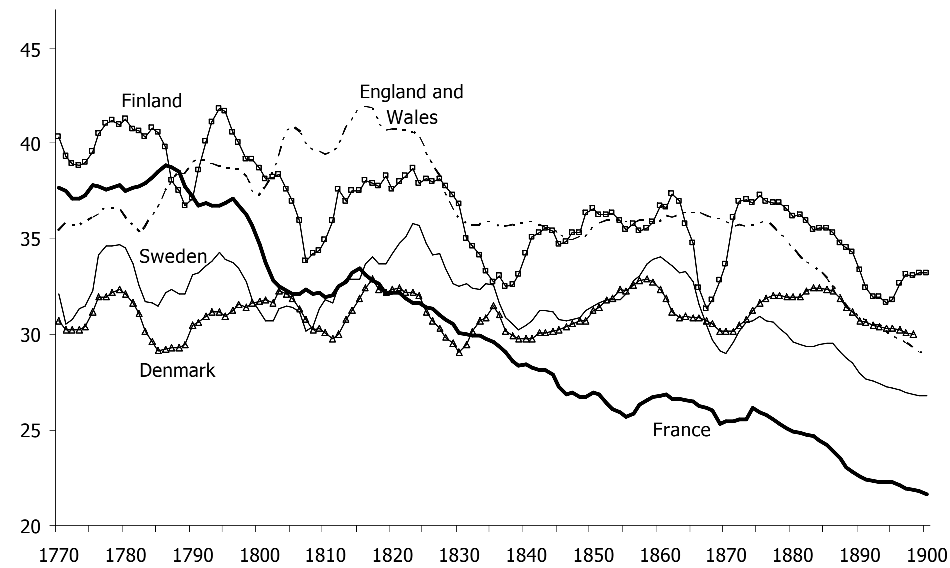
glected in standard models, such as geographical diffusion. In this way this article attempts the difficult task of combining two recently developed lines of research using agent-based simulation, a quantitative technique that has only lately become part of the social scientist's toolkit as the technological limitations that used to impede its extensive use are now slowly becoming less relevant [Axelrod, 1997, 2005; Arthur, 2005; Hedström, 2005; Gilbert, 2008; Gilbert and Troitzsch, 2005; Tesfatsion, 2005].

Preliminary results suggest that both social influence and the Revolution might partly explain the particular evolution of fertility rates in France. In simulations where we allow personal choice to dominate over the influence of neighbours we were able to mimic the aggregate behaviour of population growth well, but not that of fertility. When we allowed for more (but not total) social influence, however, the simulated fall in birth rates more closely resembled the actual decline. The model also performed reasonably well at micro level, suggesting that our choice of proxy for the 'modernisation factor' might have been a good one. Although failing to fully capture the impact on those *départements* leading the decline, simulated fertility trends –and in many cases levels—follow actual patterns in intermediate areas, and in areas that lagged behind in the demographic transition. Overall, the model provides new insights into an old problem and serves as a benchmark to assess alternative behavioural hypotheses.

# 2. Understanding the puzzle

The decline of fertility in Europe is one of those momentous events in human history that, despite a considerable amount of research in the area, still remains poorly understood. From the early attempts of the demographic transition theory to the monumental European Fertility Project, our understanding of demographic dynamics has increased considerably,[2] yet little consensus has been reached and the renewed interest triggered by the unified growth debate [Galor and Weil, 1999, 2000] calls for a re-evaluation of what we know about the topic. Available records suggest that throughout medieval and early modern times families all over the continent were quite large. Total fertility rates generated from age-specific rates tables [Flinn, 1981] suggest a woman married before her twenties would have seven to nine children during her life. The presence of the European marriage pattern [Hajnal, 1965] brought that number down for the average family, but households of four children or more were most likely the norm rather than the exception. If the early twentieth century saw families consisting of just two or three children more often than not, it is because at some stage in the nineteenth century different areas began to show a more or less steep, but definitely steady decline in birth rates.

**<u>Figure 1</u>. Crude birth rates (births per 1000 population) for selected European countries, 1770–1900**




<u>Sources</u>: For France, INED [1977: 332–333];
for England and Wales Wrigley and Schofield [1981: 531–535];
for Sweden, Denmark, and Finland, Gille [1949: 63] and Chesnais [1992: 518–541].
Values are 5-year averages, centred in the year.

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[2] Much has been written on the demographic transition and the fertility decline, and numerous works have tried to make sense of that voluminous literature. Some outstanding examples include the work of Kirk [1996] on demographic transition theory, and that of Saito [1996] on historical demography, which effortlessly discusses the achievements of the French school started by Louis Henry, the contributions of the Cambridge Population Group, and those of the monumental Princeton Project [Coale and Watkins, 1996].

Crude birth rates in Figure 1 illustrate some of the different national experiences. Before 1800 there was some diversity across regions, but the levels did not show any clear trend. By the second half of the nineteenth century, however, declining trends are already in motion. This macro perspective reveals why France, leading the decline at a slower pace by almost half a century, is one of the most interesting cases. A closer look at what was happening within the country only makes this case even more puzzling. Systematic historical information on fertility rates covering different geographical areas for the whole country is available at *département* level,[3] thanks to the efforts of the European Fertility Project [Coale and Watkins, 1986]. The story conveyed in Figure 2, which plots the Princeton index of marital fertility,[4] is quite telling.

All throughout the period it is easy to see –quite distinctively– at least two zones of low fertility, in the valley of the Seine (the Bassin Parisien) and the region of Aquitaine (the Bassin Aquitaine), increasingly spreading while the two 'islands' of high fertility, the region of Bretagne in the north-west and the Massif Central in the centre-south-east, keep shrinking. As early as 1831 one can find *départements* with indexes below 0.40 (evidencing clearly attempted and sometimes successful fertility limitation), such as Gironde, Lot-et-Garonne or Eure. As late as 1911 places like Finistère or Côtes-du-Nord were resisting change and still had indexes above 0.70 (showing little or no limitation at all). The maps suggest a (slow) process of diffusion from the Parisian and Aquitaine basins towards these 'islands' of high fertility, making France stand in contrast with other European regions where such a process was either too fast,[5] or not obvious at all. One of the aims of this paper is to make sense of this persistent heterogeneity in France.

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[3] *Départements*' total number and actual shape fluctuated with the gain or losses of nineteenth century wars but, except perhaps for the Paris area, their general pattern today differs little from that of 1790, when they were created. During the nineteenth century their total number fluctuated between 86 and 90.

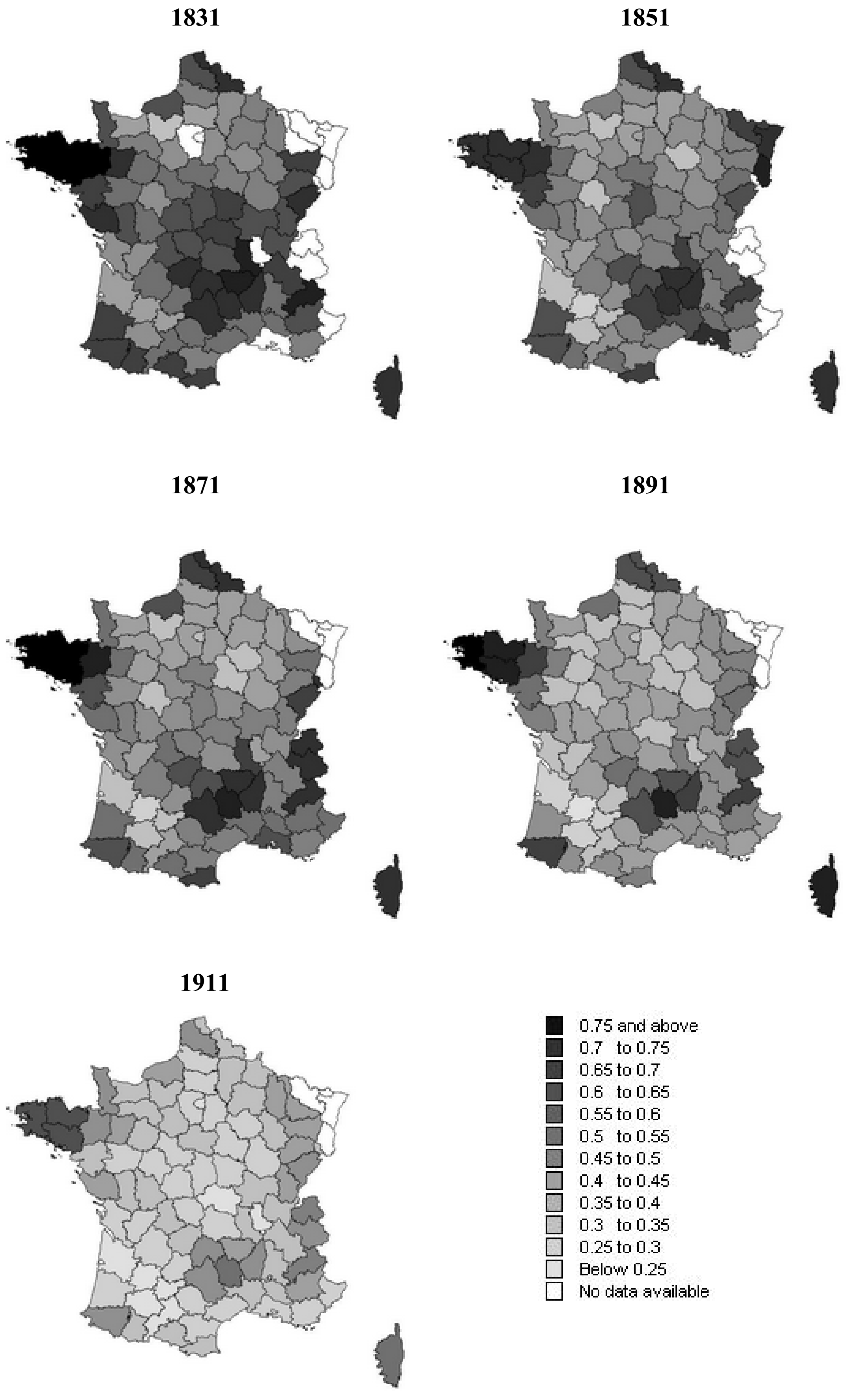
[4] The Ig index of marital fertility was developed in the context of the European Fertility Project [Coale and Watkins, 1986] and the unit of reference chosen was the biologically maximum fertility attainable. This index is defined as:

$$I_g = \frac{B_t^m}{\sum_{a=15-19}^{45-49} N_{a,t} m_{a,t} h_a}$$

Where the numerator is number of legitimate births in year $t$, $N_{a,t}$ is the number of women of age a in year $t$, $m_{a,t}$ is the proportion of women of age a actually married in year $t$ and $h_a$ is the rate of childbearing of married Hutterites at age $a$. Considering that Hutterite fertility establishes a proxy for the ceiling of what is biologically possible (they are an Anabaptist sect that adheres scrupulously to precepts forbidding the practice of contraception or abortion, and their mothers do not nurse their infants more than a few months, so they have the highest fertility rates recorded to date), Ig represents *the proportion of births with respect to the maximum biologically attainable given the age structure of married women*.

[5] As suggested in the case of England by Bocquet-Appel and Jakobi [1998].

**Figure 2. Marital fertility index (Ig) in France for each *département*, 1831–1911**




Sources: Maps are ours, constructed using data from Coale and Watkins [1986: 94–107].

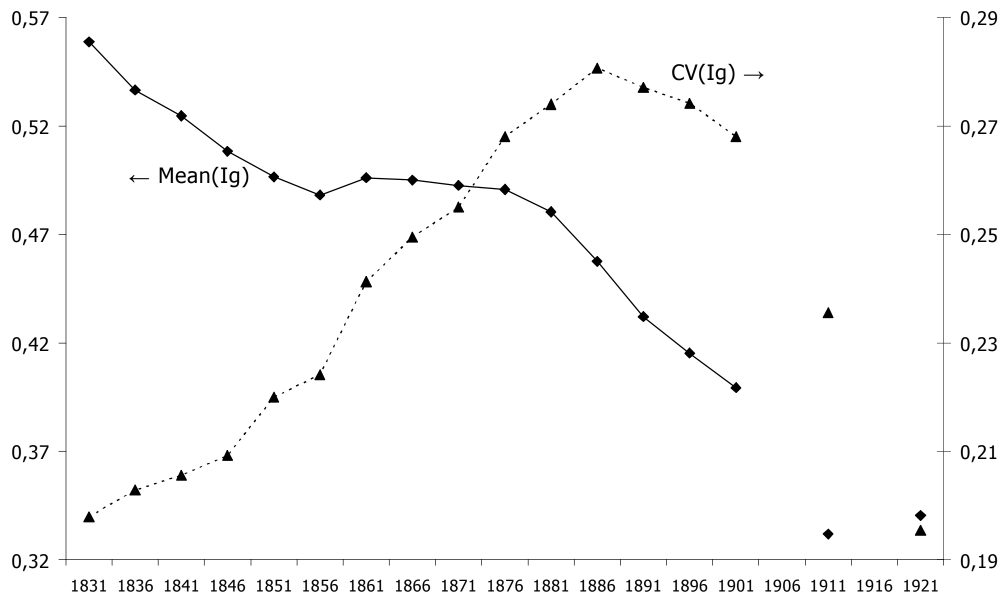
# 3. Social interaction and Diffusion

Both the presence of clustering and the spatial evolution of rates described in the previous section points towards diffusion as an appealing way of describing what happened in France[6], but it is certainly not the only plausible way to understand the evidence. One of the problems we face is that the available data do not allow us to assess whether what we see is the beginning of the story or a situation where things were already in motion. By 1831 there is considerable heterogeneity within France, but we can only speculate on whether that heterogeneity was (at least partly) already present in the eighteenth century. In fact, one argument that could be made is that what goes on during the nineteenth century results from the process of (downward) homogenisation; that is, high fertility areas beginning to mimic low fertility ones. These speculations, nevertheless, can be assessed using what we know about diffusion *vis-à-vis* homogenisation of a heterogeneous population, and what we know about the demographic history of France. Under the hypothesis of homogenisation at an (average) lower fertility level, we should see a declining mean fertility and a declining variance among *départements*. Under the hypothesis of diffusion, mean levels should also decline, but population heterogeneity must *first increase and then decrease*. Figure 3 addresses this discussion by plotting a time series of the mean and the coefficient of variation across *départements* for the time for which we have data available. The mean level of fertility is indeed falling as expected, until it stabilises around 0.32, a value that was maintained at least till the mid-twentieth century. The other line, which plots the values for the coefficient of variation for all *départements*, describes the evolution of heterogeneity. It clearly depicts an upward trend throughout the nineteenth century, sharply falling around the turn of the century, and, falling further, reaching values of 0.13 for 1961.[7] Short of a longer time range and alternative measures of heterogeneity, these appear to support the diffusion hypothesis.

[6] Systematic clustering is an indication that a feature of some areas is contaminated to other areas like a contagious virus. If contraception does *not* behave like a virus, we should expect to see *départements* randomly distributed in terms of fertility level [Bocquet-Appel and Jakobi, 1998: 190].

[7] When doing the same exercise for England one can be even more conclusive about the presence of diffusion, though it does seem to take place not only later, but at a faster rate. The level of the coefficient of variation remains constant until 1881, the 'bell' of diffusion takes barely more than half a century (versus a whole century for France) and the whole process does not drive the coefficient of variation above 0.15, when in France is always above 0.19. More sophisticated analyses suggest similar conclusions, as in Bocquet-Appel and Jakobi [1998].

**<u>Figure 3</u>. Mean and coefficient of variation of marital fertility (Ig) within departments (1831–1921)**




<u>Sources</u>: Our calculations, using data in Coale and Watkins [1986: 94–107]. Arrows indicate the axis of reference.

Diffusion stories of the fertility decline, however, have been generally met with scepticism by economists [e.g. Brown and Guinnane, 2007]. This is particularly true if we understand diffusion in a horizontal rather than a vertical sense. A particular trait could diffuse in many different ways, including vertically (from one social stratum to another), horizontally (from one place to another), or both [Bocquet-Appel and Jakobi, 1998: 181–182]. Horizontal diffusion is somewhat at odds with the adaptation hypothesis generally followed by economists, grounded on the idea that people are rational, because a change in behaviour without any change in the arguments of the maximisation problem might imply some sort of irrationality.

But this does not need to be the case. One of the easier ways to interpret the presence of diffusion of family limitation is associated with the appearance of new contraceptive techniques. Contraceptive innovation has been a crucial element in the fertility declines of the twentieth century, so it is plausible to think that in the nineteenth century the influence of contraception could have also been important. There are, however, at least a couple of reasons to doubt it. The first is that there is no clear evidence that a new contraceptive technique was instrumental in driving fertility down. Most family planning techniques used during the nineteenth century (basically *coitus interruptus* and abortion) were extensively known before then [McLaren, 1978, 1990; Van de Walle and Muhsam, 1995]. The second reason to cast doubt on the diffusion of a new contraceptive technique is that such a diffusion (i.e. that of knowledge) is expected to be relatively fast, and that was not the case in France. Knowledge about contraception is, however, not the only thing that could diffuse. The literature acknowledges that different things could be diffusing [Pollak and Watkins, 1993: 471–

472]. One is the *notion* of fertility control, or numeracy about children. The other is *preference for a different family size*. These last two are expected to spread more slowly than technology, as people tend to be conservative and avoid change for several reasons [Edwards, 1968]. A corollary of this is that, even without the appearance of a new contraceptive technique, we may still find some kind of diffusion. The results of the European Fertility Project suggest that things like linguistic differences explain a substantial part of the fertility variation [Coale and Watkins, 1986]. This does not deny the possibility that economic factors might indeed play a role in the decline of fertility. It is not only on theoretical grounds that one can justify a connection between small families and high income, as evidence both across time and space suggest that the relationship is quite strong. But especially in the early stages of the fertility decline the interplay between economic and cultural factors was probably not trivial. Most decisions about family behaviour are heavily embedded in tradition and more often than not reflect some degree of path-dependency. The relevance of diffusion effects in understanding the dynamics of fertility decline is gaining some support in the literature [Mason, 1997] and several recent papers have began to explore this line of research, such as Rosero-Bixby and Casterline [1993], Montgomery and Casterline [1993, 1996], Montgomery et al. [2001]. In this paper we will follow that line, suggesting that diffusion of social norms could explain both the low speed and the particular geographical pattern of fertility decline in France during the nineteenth century. We use the simulation model discussed in the following section to assess that hypothesis.

# 4. The simulation model

Agent-based simulation offers a new approach to the problem of social influence because it opens an experimental space to analyse the relationship between individual behaviour and emerging collective patterns. Simulation experiments allow a systematic analysis of how collective regularities change when the rules guiding individuals' behaviour are modified [Gilbert, 2008]. In doing so, agent-based models contribute to opening the 'black box' implied by many econometric models, which do not deal with the generative mechanisms that underlie the patterns they detect: statistical relationships hint at possible explanations, but they do not provide the explanation themselves [Hedström, 2005: 23]. This is the gap that agent-based models attempt to fill by using the interactions between agents as the basic building block of its dynamics and producing outcomes at the collective level that can be contrasted, and validated, with the empirical trends. As with any other modelling technique, the key in using agent-based simulation is to find the right trade-off between an accurate description of the world and the necessary simplification required of modelling it [Axelrod, 1997: 5]; but unlike econometric approaches, the logic of agent-based simulation allows a richer exploration of the complex link between the individual and the social, that is, of how small changes in the interaction of individuals can generate significantly different social outcomes [Hedström 2005: 75]. Because of this, this tool of analysis is especially attractive for the development of demographic models [Billari and Prskawetz, 2005].

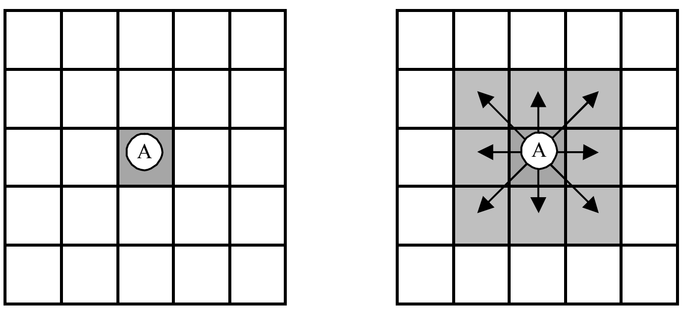
The model here is an attempt to formalise the rules of behaviour that underlay the uneven demographic transition in France. In doing so, it explicitly focuses on some aspects of the process and disregards others. The main experimental aim is to analyse the correspondence between behavioural assumptions at the level of individual interactions and the diffusion of fertility rates over space and time. In that sense, the model treats the evolution of family size as the dependent variable and the demographic and geographical constraints, calibrated empirically, as controls; the explanatory factors are the rules that determine how agents influence each other. The model will also evaluate how these rules of social influence interact with the exceptional impact of the Revolution, which is treated as an exogenous shock to the dynamics of the model. Ultimately, the model is intended as a 'middle range' simulation [Gilbert 2008: 42], as we expect to find qualitative resemblances between the dynamics of the model and the observed dynamics, and a similar distribution of outcomes. The simulation is intended to cover the historical period between 1740 and 1900. The connection of the model with the empirical data is done in at least two levels: in the initial demographic set-up, by defining how many agents of each class are in a particular place; and in the definition of the model dynamics, by defining how likely it is for an agent to die at different stages of its life and how likely it is to die with no offspring at all.

Agents in this model are born to reproduce. From the moment they are created they have an inclination to have a certain number of children, but they can only have them when they reach a mature age, and they do so at a rate of one child per period. For the sake of simplicity we have abstained from gender distinctions and marriage dynamics (agents can be interpreted as the female part of the population), but allowed them to live for fifteen periods. To facilitate comparison with demographic data, agents are classified in different groups of 'age': newborns, young1 to young3, mature1 to mature5, and old1 to old6.[8] Agents have two attributes associated to their age: the probability of death, a rate that is determined empirically; and fertility, which results from rules endogenous to the model. Only agents classified as mature are able to create new agents and therefore reproduce the population. The particular characteristic that we give the agents is that they do not only consider their own inclination to have children, but also the desired offspring of their neighbours. In other words, the number of offspring agents will create is a function of the number of offspring *they* and *their neighbours* want to have. In order to decide the number of offspring they want to have, mature agents are endowed with the following decision rule:

$$y_{i,t}^{m} = \alpha z_i + \beta \frac{1}{n_p} \sum_{j=1}^{n_p} y_{j,t-1}^{m} + \left(1 - \alpha - \beta\right) \frac{1}{n_v} \sum_{j=1}^{n_v} y_{j,t-1}^{m}$$

When the agent becomes mature at time *t*, she establishes her desired number of offspring ( $y_{i,t}^{m}$ ) by considering not only her own inclination to have children ($z_i$), but also the average desired offspring ( $y_{j,t-1}^{m}$ ) of all those agents that were mature in the previous year and are relatively close to her. Own inclination is determined by a normal distribution with mean $\mu$ and standard deviation $\sigma$, parameters that are inherited from her mother.[9] We distinguish two levels of impact of the environment, that generated by $n_p$ neighbours and that by $n_v$ extended neighbours. Figure 4 illustrates this.

**Figure 4. Agent's neighbours**




Neighbours ($\beta$) Extended neighbours ($1–\alpha–\beta$)

The landscape agents populate is modelled as a grid. Various agents can cohabit in the same cell and it is the influence of these agents that the parameters $\alpha$ and $\beta$ capture: they determine the relative weights of the desired offspring of an agent and that of its neighbours, respectively, and they provide the basic experimental space of the model. Basically, the larger the value of $\alpha$, the more weight agents will give to their

[8] The five-year ranges are standard in demographic analysis and allow a straightforward association with empirical data such as mortality rates.

[9] From this formulation it is clear that we are treating fertility choice more or less as a black-box. Given the complexity of making all agents simultaneously choose the fertility level, making them assess other variables such as income, education levels, or mortality rates could increase computational costs enormously. It is not technically impossible, however, and future research could address these issues.

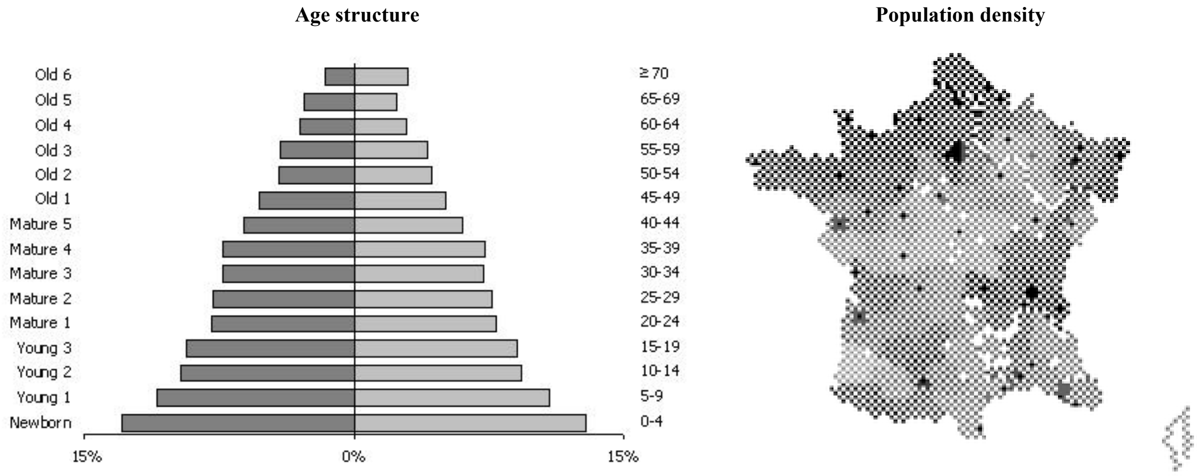
own preferences, and the less vulnerable they will be to social influence. On the other hand, the larger the value of *β,* the more relevant the neighbours' inclination will be to determine an agent's decision. Finally, the lower *α* becomes with respect to the same *β*, the more relevant the extended neighbourhood will be in influencing an agent. In a nutshell, these parameters regulate the scope of social influence and it is by tuning their values that the simulation tests to what extent social influence affects the collective outcomes.

To make the model resemble reality we incorporated some of the things we know about the geography and demographic history of France in the set-up of the environment where the agents interact. The space that agents occupy is a grid that reproduces the map of France.[10] The simulation starts with roughly 100,000 agents which are placed on the grid following some empirical guidelines. Due to the lack of estimates about the number of people in the different age groups for each *département* around 1740 (let alone for every 100 square kilometre area), we had to make some assumptions. Henry and Blayo have estimated age pyramids for early modern France and we have taken as reference the one corresponding to 1740 [Henry and Blayo, 1975: 92–93]. Figure 5 shows the correspondence between our set-up of the model and the actual data. As can be seen there, the resemblance is rather good.[11] We are making the assumption that this relationship among ages remains more or less constant throughout France, which is probably not the case, but we believe this is not a major drawback for the purposes of our model. Population densities provide a second anchoring point between the set-up of the model and actual data. The earliest year for which we have information (population by *département*, and number of people in major cities) about population density is 1801 [Service de la Statistique Général de France, 1878], and agents are distributed in the grid according to these data.

[10] Each cell in the grid represents roughly 100 square kilometres (i.e. roughly a 10x10 km area), and there are a total of 5308 cells.

[11] The most substantial differences would be in the oldest segment of the population because, for simplicity, in the simulations, we only allow agents to live to 75. Since most of the relevant action takes place among younger people, this should not be a substantial problem.

**<u>Figure 5.</u> Anchoring the initialisation structure to empirical estimates**




<u>Notes</u>: On the age structure figure on the left, the axis in the bottom indicates the proportion of each age-group with respect to the total population. Actual data for 1740 France comes from Henry and Blayo [1975: 92–93].

The map on the right depicts the population density as simulated in the model; darker patches are more populated.

According to this initial set-up, not all agents will eventually have children. After Hajnal's seminal contribution [Hajnal, 1965] it is a more or less established fact that Europe was characterised by a particular marriage pattern, where women married late and some did not marry at all. We follow the estimates of Weir [1994] for the proportion of women married by age-group. As might be expected, these proportions do not remain completely constant over the whole period under study here, but they are more or less stable until the take off of the second part of the nineteenth century. The values we picked are average proportion of unmarried women for the 1740–1850 period: 72%, 43%, 28%, 23%, and 22% for each age group corresponding to mature1 to mature5 respectively. Also relevant when modelling this type of demographic process is the role of decreasing fecundity with age, or lack of fecundity at all. Although male sterility is not uncommon, it is normally female sterility that is more binding and this is present in at least three forms. From the time they are born, women are sterile until they reach menarche around the mid-teens. For simplicity, in our model we assume that only mature agents have children, so we are implicitly considering that all agents are sterile (or unmarried) till then. Then, we can distinguish primary sterility, which refers to women who can never have children, and secondary sterility, which emerges at some stage after the woman has been fertile for a period [Boongarts, 1975: 293]. These normally vary from person to person. There are different biological factors affecting both types of sterility, so estimates could vary between populations considerably, and it is often difficult to disentangle sterility from actual contraception in historical data, especially for younger ages. Hence, we take the conservative approach of assuming no primary sterility at all, and secondary sterility affecting only the last two groups of matures. For this, we take Henry's estimates for a series of European populations in the modern period [Henry, 1961: 85] as upper-bounds and impede procreation of 15% of mature 4 and 30% of mature 5. With these data we obtain a series of the expected proportions of agents able to have children. Following this rule, mature agents can generate new agents until they reach the number determined by the behavioural equation or until they enter the old category.

The simulation runs for a total of 36 periods, each representing five years, starting from 1720 and stopping in 1900. With every time step, agents move upwards in the age scale. Once an agent is born, it will live for up to 15 periods, although random agents in all categories can disappear at any time in proportion to the mortality rate attached to their age.[12] The simulation keeps track of the number of agents in each age group; it also records the number of offspring that agents want to have and calculates the average for each cell in the map. This creates a census of the simulated population as it evolves over time. The simulation then applies the mortality rates in accordance to the age of the agents and the *département* in which they are located and shifts the remaining agents to the next age group. Agents with age >70 all die and are replaced by the agents in the previous age group. The agents entering the mature category are given a desired number of offspring as determined by the behavioural equation. New agents classified as newborns are finally created in the last procedure: if a mature agent has not yet reached the maximum number of offspring she wants to have, is married and not sterile, she will create a new agent. This loop is repeated 36 times, at which point the simulation stops.

[12] Mortality rates were estimated by Bonnieul [1997] for all age ranges every five year throughout the nineteenth century. For pre–1800 simulations we assumed the earliest rates available. Post–1800 we adjusted infant mortality every ten years, as this was most affected during the period, and kept the rest constant at early nineteenth-century levels.

# 5. The impact of the revolution

The only exogenous impact we allow in the simulation from the moment it starts is the shock of the Revolution, which activates when the calendar of the model reaches 1790. There are many reasons to think the events of 1789 might have been connected with the fertility decline. A recent body of literature suggests (more as an empirical pattern than in terms of a theory) that social upheavals have a profound effect on the evolution of birth rates [Binion, 2001; Caldwell, 2004; Bailey, 2006]. Caldwell highlights, for example, the negative consequences these crises have on both the expectations of individuals and their material resources, which in turn affect short- and long-term fertility choice. Binion, with a more optimistic view similar to that of Bailey, points out that the democratic nature of the French and American revolutions changed the relationship between the individual and society, and ultimately the attitude of the individual towards the active control of his or her own future (including family size). In a similar vein, some arguments build on the effect of the improvement in the rights of women on conjugal relationships [e.g. Flandrin, 1979]. Doepke and Tertilt [2007], for example, suggest that increased women's rights (which might well be one of the outcomes of the Revolution) could have motivated a search for quality of children, not only due to increases in opportunity costs for the mother, but also for the daughters.

Another aspect usually brought up is that of religion. There is evidence suggesting a connection between religion and fertility behaviour.[13] The secular nature of the Revolution, and the break it instigated between society and the church, might partly explain the decline. The fact that France remains eminently Catholic to this day could suggest that the impact of the Revolution was probably not felt in religion. But the shock seems to have been more subtle, as, in the nineteenth century, while 'the liturgical aspects of Catholicism […] were in popular demand; the attempt to impose on the mass of the people a rigorous code of thought and behaviour was not […] It was of course especially unacceptable where sexual matters were concerned' [Gibson, 1989: 244]. Up to the early nineteenth century, Catholicism, a religion with a particular code with respect to family behaviour, remained the main norm-setter in France and took a strong stance against contraception, condemning heavily the 'sin of Onan,', the main technique couples had to control fertility at the time [Flandrin, 1979: 194–196; Gibson, 1989: 185–186]. But already during the eighteenth century there were signs of de-Christianisation. Attendance at mass became less frequent, the number of people joining the clergy diminished, and the proportion of religious books owned by those rich enough to buy them fell considerably [Gibson, 1989: 3]. 'Anomalies' in sexual behaviour also became increasingly common, and evidence suggests that not only was contraception becoming more common, but also illegitimacy and bridal pregnancy. Although the early nineteenth century saw a religious revival, the anticlericalism and de-Christianisation of the Revolution had shaken the church to its very foundations; this might have created the link between the Revolution, religion and fertility. 'The hiatus in clerical control consequent upon the Revolu-

[13] See Derosas and van Poppel [2006] for an extensive overview of the recent research on this.

tion seems to have enabled at least some French men and women to break free from old constraints.' [Gibson, 1989: 244–245].

The secularisation triggered (or simply manifested) by the Revolution could be interpreted in many ways. Some of the potential impacts of religion on fertility are obvious. Religion, after all, conveyed much of the normative framework and was a key component in the social capital of French society. Recent work on the role of social networks in fertility choice has raised the point that fertility could well be a coordination problem [Kohler, 2001: 143–144]. If that were the case, *both* history and expectations play a role in determining fertility levels; a major social upheaval could break their long term equilibrium, making room for a change. The direction of causality, nevertheless, could also go the other way. We can see families wanting to have less children and being impeded by the Church. The effect of the Revolution in this respect is to reduce the costs of not following some of the mandates of the Church. An alternative reading of our model is that there are some external reasons driving fertility down and that the Revolution provides the trigger to make preferences and behaviour coincide. And yet, arguments not primarily religious are still consistent with the decreasing influence of the Church. Weakly religious areas could have been more sensitive to the institutional changes brought by the Revolution and *these* changes could have had an impact on fertility. A clear example of this is the laws of inheritance that were affected by the new government. Although supposedly affecting the whole nation simultaneously, it has been suggested that these laws were unequally applied according to custom [Brandt, 1901], and in this the influence of the Church could have been instrumental. A similar point was made by Weir [1983] related to the change in land property rights.

The discussion above suggests that for our analysis we need some kind of measure of the impact of the Revolution on the population or the level of intensity of the Catholic faith in different areas. Such a map is probably impossible to build, but there are reasons to believe this geographical division did not change that much until the detailed *carte Boulard* of 1947.[14] It is not really clear when these regional differences were first established, but we are ready to claim that at least by the time of the Revolution they were already present. The variable we consider here resembles the *carte Boulard* but it has a direct association with the Revolution. In 1791 the National Assembly required priests to swear an oath of loyalty to the Revolution, ultimately implying that they were servants of the public. The proportion of priests voting allegiance to the Revolution varied substantially throughout the country and it is this variance that we use in the analyses. It is not our intention here to oversimplify the interpretation of the oath. As it has been emphasised extensively by Timothy Tackett,

[14] The *carte Boulard* is a detailed description of the areas of stronger influence of the Catholic Church made by Canon Boulard for the year 1947. This map appears in the classic work of Gabriel Le Bras [1955: 324]. It is noteworthy that in the middle of the twentieth century the same areas that maintained a strong attachment to the Catholic faith were the same identified with strong religiosity by other measures, such as students' participation in religious schools in the second part of the nineteenth century [Murphy, 2008]. Gibson points out that scattered indices of vocation to priesthood, publication of religious books and attendance to mass suggest a pattern rather similar to that of mid-twentieth century [Gibson, 1989: 170–177].

probably the utmost authority on the history of the oath, the reasons behind the heterogeneity of the oath's success are hard to figure out [Tackett, 1986: 287–300, and 2006: 545–546]. But there are indeed reasons to believe the pattern of oath-taking could be correlated with the impact of religion on society that we want to measure; this interpretation is not entirely forced.[15] Tackett himself suggests that 'almost everywhere laypeople exerted pressure on the clergy to accept or reject the oath, with the oath ceremony providing the occasion for a *de facto* referendum on the general religious and secular policies of the Revolution' [Tackett, 2006: 546].

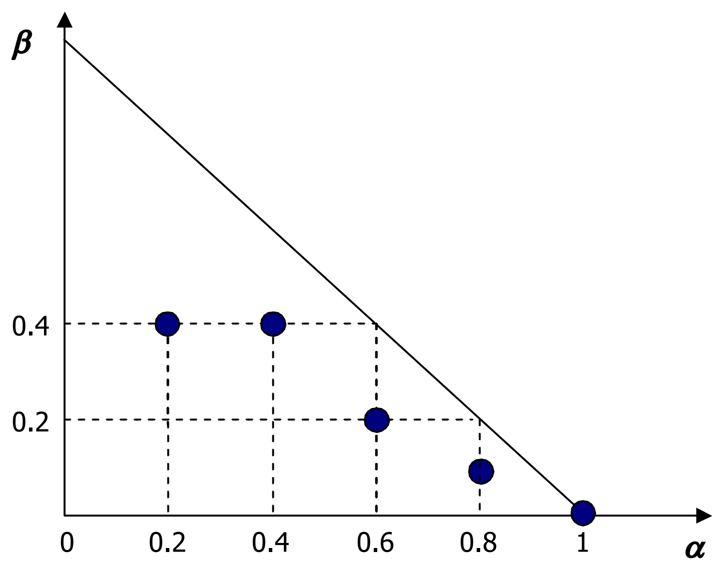
As discussed above, the Revolution can be thought of as helping to weaken the link between religion (or, more generally, pre-existing social norms) and reproduction. We incorporate its impact as follows: we mentioned earlier that agents in our model draw their own inclination to have children from a normal distribution with mean $\mu$; we will now assume that at the time of the Revolution a certain number of agents will draw that inclination from another distribution with a lower mean ($\mu_{rev}$). The number of agents in each *département* that become 'revolutionary' will be determined by the proportion of priests in that area swearing the oath of faith. In this very simple specification the French Revolution has only a one-time effect on religious practices; some lineages become 'revolutionary' and other families are not affected beyond the scope of the behavioural equation each agent follows. This is probably rather conservative, as it is not unlikely that over the nineteenth century such an idea spread well beyond those directly influenced in 1789, but it is a reasonable approximation as a starting point.

[15] The measure has already been used as a proxy for religiousness in a recent study on trust and financial markets by Hoffman et al. [2007: 16–17].

# 6. Re-playing the tape of history: Preliminary Results

With all the components of the model in place we can turn now to its calibration, which we do by running several simulations and figuring out which set of parameters fit the data better. Since we wanted to assess the impact of different patterns of social interaction we produced simulations for several sets of parameters ($\alpha$, $\beta$) ranging from very large social influence to no influence at all. Here we are going to discuss the five different parametric combinations plotted in Figure 6. For each of these pairs we let the programme generate sets of 10 simulations up to the time of the Revolution for all different $\mu$s within a sensible range (from 1.0 –equivalent to 2 child per family in actual data- to 4.0 –equivalent to 8-, with increments of 0.1),[16] assessing the evolution of population and fertility (Ig) levels for the averages of those simulations.[17]

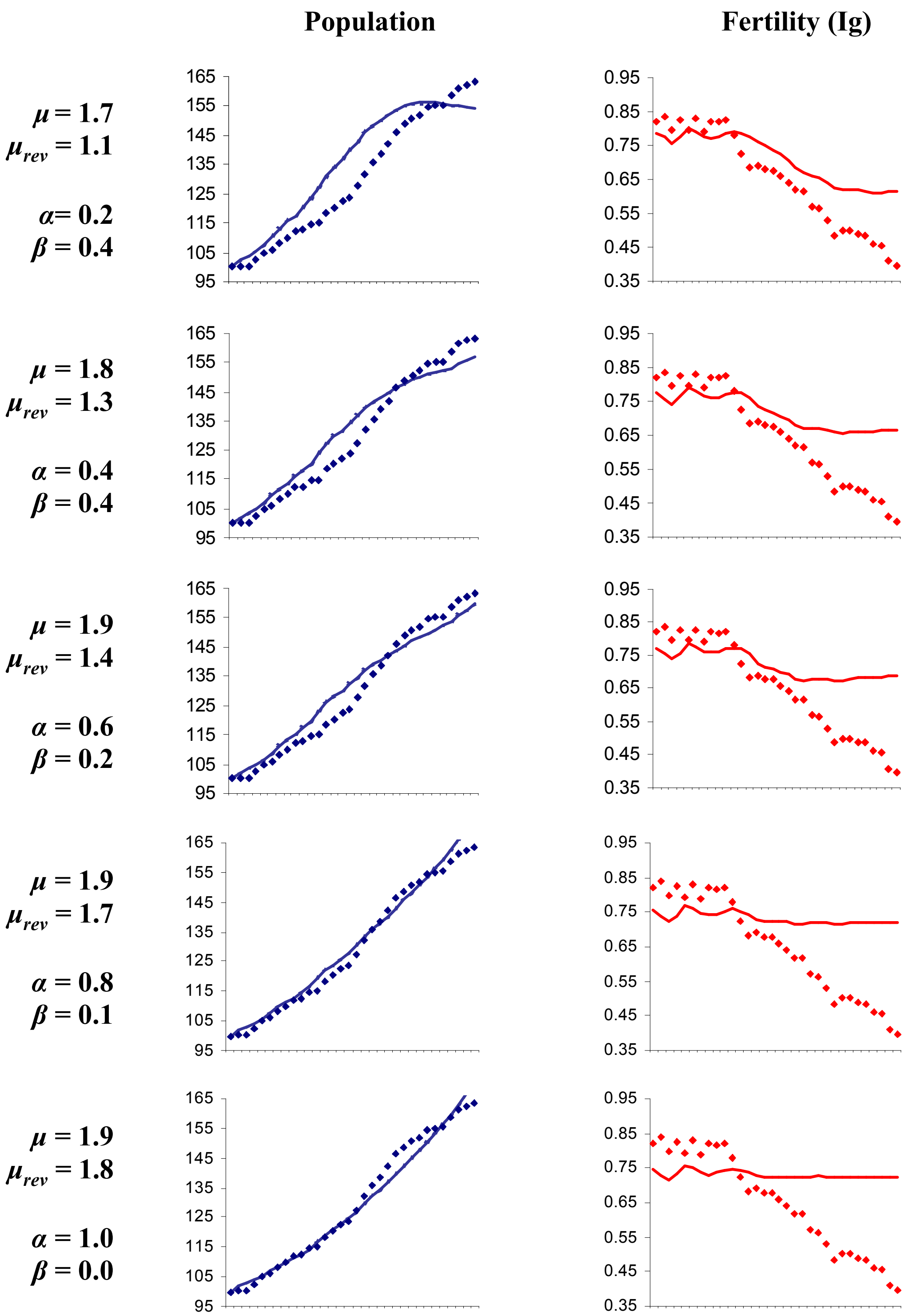
**Figure 6. Different levels of social influence**




[16] All throughout the simulations we have assumed $\sigma$ to be 0.45, which is more or less the average value for empirical populations as estimated from age-specific fertility tables in Flinn [1981]. Further research could explore how different assumptions on this parameter might have affected the evolution of the system.

[17] Since we have built the model in such a way that we know the married population of females for each age cohort (i.e. the matures that are allowed to have children) and the number of births, with only the fertility rates of the Hutterites [in Henry, 1961] we were able to estimate the values of Ig for our simulated society directly from the output of the computer programme.

**Figure 7. Actual and simulated levels of population and fertility, France (1740–1900)**




Notes: Dotted lines indicate actual values starting and smooth lines correspond to simulation. Actual and simulated populations are set equal to 100 in 1740.

We found that the degree of social influence already has some effect even before the Revolution; simulations where social influence was larger required a smaller $\mu$ to sustain the same population levels than larger $\alpha$ needed. This probably has to do with the families aiming towards more stable means and reducing the number of small families. For $\alpha$ below 0.5, a $\mu$ between 1.7 and 1.8 produced the best results, but with $\alpha$ higher than that we needed means in the range of 1.9–2.0, values that are more or less consistent with historical data if we apply marriage rates to age-specific fertility rates.

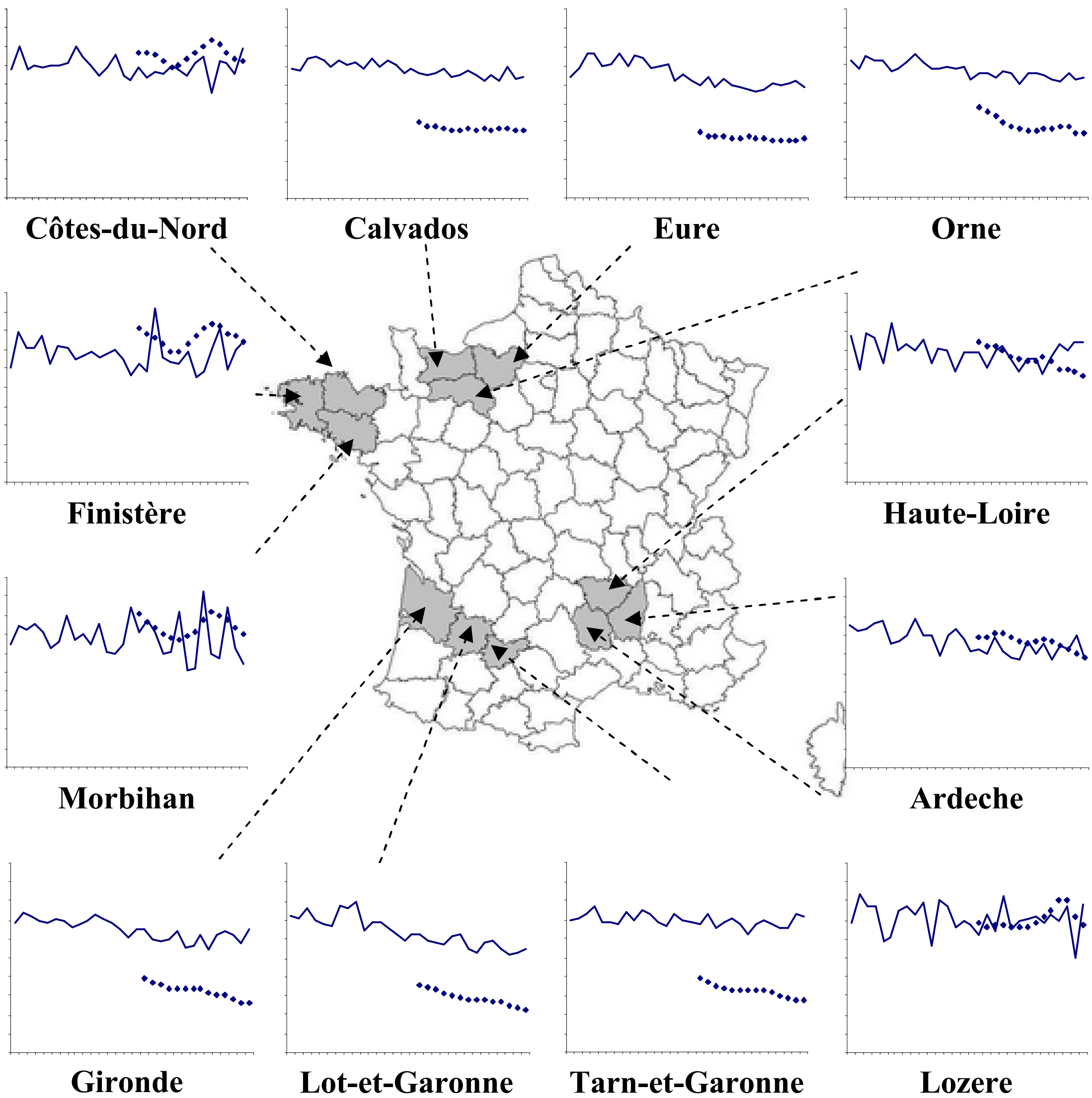
To assess the impact of the Revolution, we restricted the simulations to those ranges of $\mu$ that minimised a basic measure of goodness of fit (the sum of squares between actual and simulated population levels) for the period up to the Revolution. We then ran simulations for the entire period trying a whole range of values for $\mu_{rev}$. Best fits for each ($\alpha$, $\beta$) pair are plotted in Figure 7. Results were mixed but, overall, the performance of the model for these aggregate values was rather good. Again, smaller $\alpha$s required smaller $\mu$s (and in this case also smaller $\mu_{rev}$s) and although they did not seem to match the evolution of population as well,[18] they seemed to do a good job tracking the fertility decline. Interestingly enough they also needed a larger fall in $\mu$. Cases where $\alpha$ was equal or close to 1 required less substantial falls in the mean desired family size to match the population trend well, but failed considerably in producing a decline after 1800.

Taking the case where ($\alpha$, $\beta$) = (0.4, 0.4) as the one that tracked both series more accurately, we looked closer at the performance of the model on the *département* level. For the sake of clarity we have plotted only selected cases in the following two figures. Figure 8 describes the evolution of the model in some *départements* that can be easily identified as leaders (Calvados, Eure, Orne, Gironde, Lot-et-Garonne, Tarn-et-Garonne) or laggards (Côtes-du-Nord, Finistère, Morbihan, Haute-Loire, Ardèche, Lozère) of the fertility decline. It is clear from those graphs that laggards were relatively well tracked, as the high level of fertility they maintained into the nineteenth century was mimicked by the simulation. Although picking up a small general downward trend, the levels of fertility for the leaders were largely overstated.

At least two characteristics of the model could explain this problem. On the one hand, we already mentioned that the model does not allow families to *become revolutionary* after 1800, which probably puts upward pressure on those *départements* where progressive attitudes might have influenced other ‘lineages’. On the other hand, the model assumes homogeneity across all individuals in terms of social influence (that is, $\alpha$ and $\beta$ remain constant for all agents). It is certainly not implausible to think that the propensity to follow others could vary across regions and, in particular, it is likely that areas leading the decline were more prone to be more ‘individualistic’. These effects might of course be reinforced by other sources of heterogeneity the agents use to draw their desired family size, such as differences in income, education, etc. that the model is simply not incorporating and are ‘hidden’ in the normal distribution.

[18] In this specification of the model we only tried $\mu$s up to the first decimal value and perhaps fitting less discrete values might provide better results.

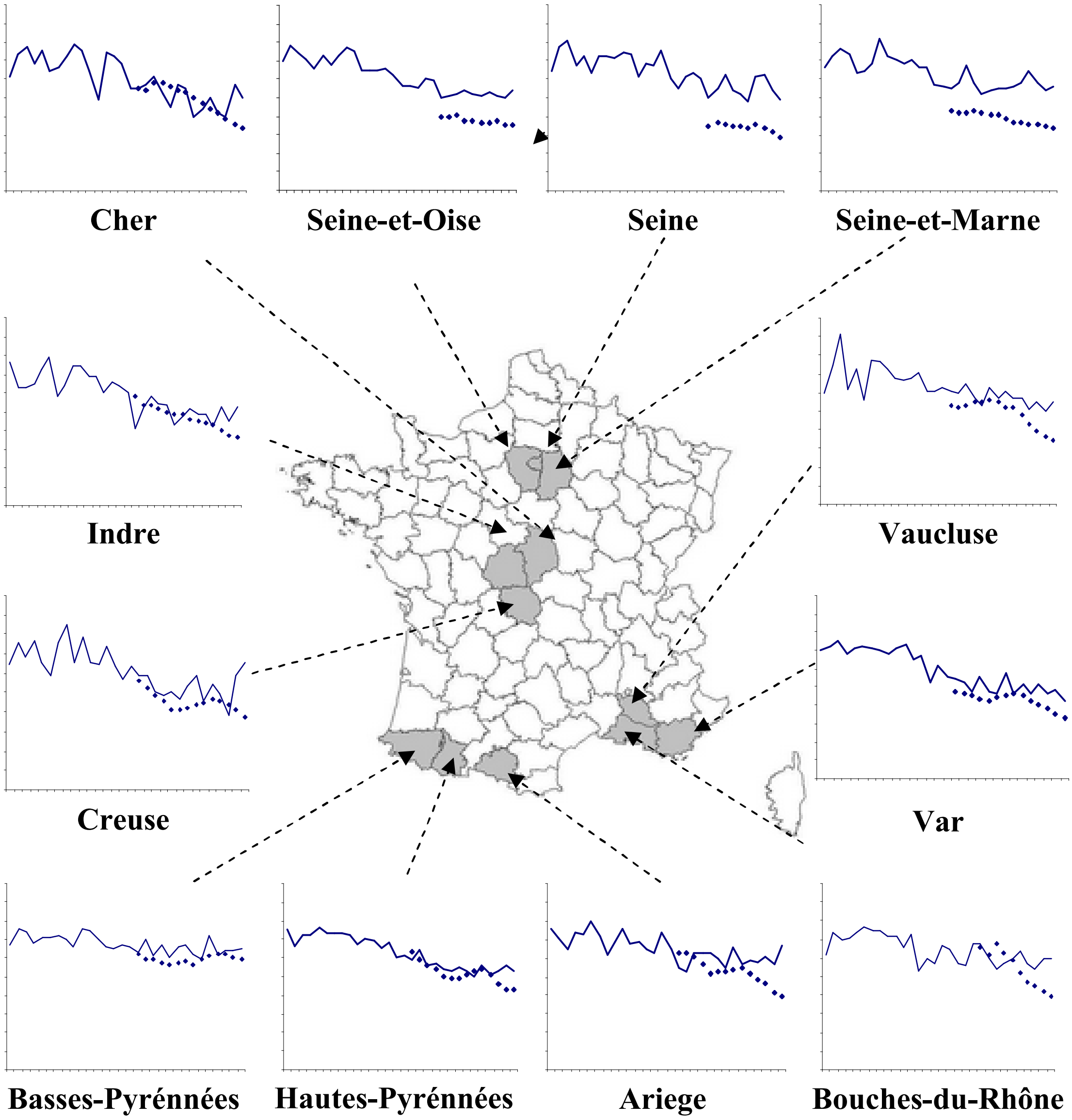
**Figure 8. Actual and simulated levels of fertility (Ig) with $\alpha = \beta = 0.4$, France (1740–1900): Leaders and laggards**




Notes: Dotted lines indicate actual values starting in 1831, whereas smooth lines correspond to simulation starting in 1741. Both finish in 1896.

The model still does a decent job for many of the non-extreme areas, as some of those illustrated in Figure 9 can show. In every case the general trend of the decline appears to be tracked well, in some cases with outstanding results, suggesting the type of heterogeneity we used (i.e. the proportions of Ecclesiastical oaths) was probably suitable for perceiving the nature of the problem we were trying to model. For areas not plotted here results were mixed but trends tended to coincide. The few cases where tracking was not that good were associated with areas only scantly populated (where simulations were probably less stable), those on the north-east borders, where influence from other countries probably played a non-minor role (interestingly enough, this was not the case in the Pyrenees), and areas that were leaders rather than followers.

**Figure 9. Actual and simulated levels of fertility (Ig) with $\alpha = \beta = 0.4$, France (1740–1900): selected areas**




Notes: Dotted lines indicate actual values starting in 1831, whereas smooth lines correspond to simulation starting in 1741. Both finish in 1896.

# 7. Concluding Remarks

Despite its simplicity, the model developed in this paper appears to be a good first approximation in describing the fertility decline in France using agent-based simulation techniques. It shows that social influence probably played a role in the particular dynamic followed by fertility rates and suggests that part of the different regional trend could be traced back to the heterogeneous impact of the Revolution. Simulations where some (but not total) social influence was present were better able to track the fall in birth rates than those where this influence was ignored. Far from trivial, this outcome highlights that interpersonal interactions –an issue only marginally discussed in the literature– do matter. The results at micro level were also quite satisfactory, suggesting that our choice of the proxy for the 'modernisation factor' was probably appropriate. This calls for a need to revisit the relationship between institutional framework (religious or other) and fertility choice during the decline. Even if there are economic reasons behind the desired fall in fertility (the fall in $\mu$, which in our model remains as an exogenous shock), cultural constraints can indeed affect the specific dynamics of the system and we need to learn more about them. The failure to fully capture the impact on those *départements* leading the fall in birth rates, on the other hand, points towards some of our model's limitations, but it emphasises the ways in which it could be improved. This could be by either making the behavioural rule more flexible or by making it richer by including other potential variables already suggested by the fertility choice literature started by Becker almost half a century ago. Although computationally more costly, these extensions are indeed possible using similar agent-based models. This type of modelling then comes up as a promising way of exploring lines of research so far neglected in the literature and further work in the area could illuminate other aspects of this momentous transformation

# REFERENCES


**Arthur, W. Brian [2005]**; 'Out-of-Equilibrium Economics and Agent-Based Modeling', in K. Judd and L. Tesfatsion (Eds.) [2005]; *Handbook of Computational Economics – Vol. 2: Agent-Based Computational Economics* (Elsevier/North-Holland, Amsterdam), pp. 1551–1564

**Axelrod, Robert [1997]**; *The Complexity of Cooperation: Agent-Based Models of Competition and Collaboration* (Princeton University Press, Princeton)

**Axelrod, Robert [2005]**; 'Agent-Based Modeling as a Bridge between Disciplines', in K. Judd and L. Tesfatsion (Eds.) [2005]; *Handbook of Computational Economics – Vol. 2: Agent-Based Computational Economics* (Elsevier/North-Holland, Amsterdam), pp. 1565–1584

**Bailey, Amy Kate [2006]**; 'Fertility and Revolution: How Does Political Change Influence Reproductive Behavior?', *MIMEO* (http://sneps.net/RD/uploads/ASEN_Bailey.pdf)

**Billari, Francesco and Alexia Prskawetz [2005];** 'Studying population dynamics from the bottom-up: the crucial role of agent-based computational demography', *MIMEO* (http://iussp2005.princeton.edu/download.aspx?submissionId=51988)

**Binion, Rudolph [2001]**; 'Marianne in the Home. Political Revolution and Fertility Transition in France and the United States', *Population (English Selection)*, Vol. 13, No. 2, pp. 165–188

**Bocquet-Appel, Jean-Pierre and Lucienne Jakobi [1998]**; 'Evidence for a Spatial Diffusion of Contraception at the Onset of the Fertility Transition in Victorian Britain', *Population (English Selection)*, Vol. 10, No. 1, New Methodological Approaches in the Social Sciences, pp. 181–204

**Bonneuil, Noël [1997]**; *Transformation of the French Demographic Landscape, 1806–1906* (Clarendon Press, Oxford)

**Bongaarts, John [1975]**; 'Why High Birth Rates Are So Low', *Population and Development Review*, Vol. 1, No. 2, December, pp. 289–296.

**Brown, John C. and Timothy W. Guinnane [2002]**; 'Fertility Transition in a Rural, Catholic Population: Bavaria, 1880–1910', *Population Studies*, Vol. 56, pp. 35–50

**Brown, John C. and Timothy W. Guinnane [2007]**; 'Regions and Time in the European Fertility Transition: Problems in the Princeton Project's Statistical Methodology', *Economic History Review*, Vol. 60, No. 3, pp. 574–595

**Caldwell, John C. [2004]**; 'Social Upheaval and Fertility Decline', *Journal of Family History*, Vol. 29, No. 4, October, pp. 382–406

**Chesnais, Jean-Claude [1992]**; *The Demographic Transition: Stages, Patterns, and Economic Implications* (Clarendon Press, Oxford)

**Coale, Ansley and Susan C. Watkins (Eds.) [1986]**; *The Decline of Fertility in Europe: the Revised Proceedings of a Conference on the Princeton European Fertility Project* (Princeton University Press, New Jersey)

**Derosas, Renzo and Frans van Poppel (Eds.) [2006]**; *Religion and the Decline of Fertility in the Western World* (Springer, Dordrecht – Netherlands)

**Doepke, Matthias and Michèle Tertilt [2007]**; 'Women's Liberation: What Was in It for Men?', *MIMEO* (http://web.uvic.ca/econ/tertilt.pdf)

**Edwards, Ward [1968]**; 'Conservatism in Human Information Processing', in B. Kleinmuntz [1968]; *Formal Representation of Human Judgement* (John Wiley & Sons, New York), pp. 17–52

**Flandrin, Jean-Louis [1979]**; *Families in Former Times: Kinship, Household and Sexuality in Early Modern France* (Cambridge University Press, Cambridge)

**Flinn, Michael W. [1981]**; *The European Demographic System, 1500–1820* (The Johns Hopkins University Press, Baltimore, Maryland)

**Galor, Oded and David N. Weil [1999]**; 'From Malthusian Stagnation to Economic Growth', *American Economic Review*, Vol. 89, No. 2, May, pp. 150–154

**Galor, Oded and David N. Weil [2000]**; 'Population, Technology, and Growth: From Malthusian Stagnation to the Demographic Transition and Beyond', *American Economic Review*, Vol. 90, No. 4, September, pp. 806–828

**Gibson, Ralph [1989]**; *A Social History of French Catholicism 1789–1914* (Routledge, London)

**Gilbert, Nigel and Klaus G. Troitzsch [2005]**; *Simulation for the Social Scientist – Second Edition* (Open University Press, Maidenhead)

**Gilbert, Nigel [2008];** *Agent-Based Models* (Sage Publications, London)

**Gille, H. [1949]**; 'The Demographic History of the Northern European Countries in the Eighteenth Century', *Population Studies*, Vol. 3, No. 1, June, pp. 3–65

**Hajnal, John [1965]**; 'European Marriage Patterns in Perspective', in D. V. Glass and D. E. C. Eversley (Eds.) [1965]; *Population in History: Essays in Historical Demography* (Blackwell Publishers, Cambridge Mass.), pp. 101–143

**Hedström, Peter [2005]**; *Dissecting the Social. On the Principles of Analytical Sociology* (Cambridge University Press, Cambridge)

**Henry, Louis [1961]**; 'Some Data on Natural Fertility', *Eugenics Quarterly*, Vol. 8, pp. 81–96

**Henry, Louis and Yves Blayo [1975]**; 'La population de la France de 1740 a 1860', *Population (French Edition)*, Vol. 30, pp. 71–122

**Hoffman, Philip T., Gilles Postel-Vinay, and Jean-Laurent Rosenthal [2007]**; 'Is Trust an Ultimate Cause? Its Role in the Long Run Development of Financial Markets in France', *MIMEO* (http://international.ucla.edu/cms/files/hpvrtrustrev2.pdf)

**INED -Institut National d'Etudes Démographiques- [1977]**; 'Sixième rapport sur la situation démographique de la France', *Population*, Vol. 32, No. 2, March-April, pp. 255–338

**Kirk, Dudley [1996]**; 'Demographic Transition Theory', *Population Studies*, Vol. 50, No. 3, November, pp. 361–387.

**Kohler, Hans-Peter [2001]**; *Fertility and Social Interaction: An Economic Perspective* (Oxford University Press, Oxford)

**Lesthaeghe, Ron [1980]**; 'On the Social Control of Human Reproduction', *Population and Development Review*, Vol. 6, No. 4, December, pp. 527–548

**Mason, Karen O. [1997]**; 'Explaining Fertility Transitions', *Demography*, Vol. 34, No. 4, November, pp. 443–454

**McLaren, Angus [1978]**; 'Abortion in France: Women and the Regulation of Family Size 1800–1914', *French Historical Studies*, Vol. 10, No. 3, Spring, pp. 461–485

**McLaren, Angus [1990]**; *A History of Contraception: From Antiquity to the Present Day* (Basil Blackwell, Oxford)

**McQuillan, Kevin [1999]**; 'Religious Values and Fertility Decline: Catholics and Lutherans in Alsace, 1750–1870', in R. Leete (Ed.) [1999]; *Dynamics of Values in Fertility Change* (Oxford University Press, Oxford)

**Montgomery, Mark R. and John B. Casterline [1993]**; 'The Diffusion of Fertility Control in Taiwan: Evidence from Pooled Cross-Section Time-Series Models', *Population Studies*, Vol. 47, No. 3, November, pp. 457–479

**Montgomery, Mark R. and John B. Casterline [1996]**; 'Social Learning, Social Influence, and New Models of Fertility', *Population and Development Review*, Vol. 22, Supplement: Fertility in the United States: New Patterns, New Theories, pp. 151–175

**Montgomery, Mark R., John B. Casterline and Frank Heiland [2001]**; 'Social Networks and the Diffusion of Fertility Control', *MIMEO* (http://www.demogr.mpg.de/Papers/workshops/010221_paper04.pdf)

**Murphy, Tommy E. [2008]**; 'Old Habits Die Hard (Sometimes): What Can *Departement* Heterogeneity Tell Us About the French Fertility Decline?', *MIMEO* (http://www.nuffield.ox.ac.uk/users/murphy/files/Old_habits.pdf)

**Rémond, René [1999]**; *Religion and Society in Modern Europe* (Blackwell Publishers, Oxford)

**Rosero-Bixby, Luis and John B. Casterline [1993]**; 'Modelling Diffusion Effects in Fertility Transition', *Population Studies*, Vol. 47, No. 1, March, pp. 147–167

**Saito, Osamu [1996]**; 'Historical Demography: Achievements and Prospects', *Population Studies*, Vol. 50, No. 3, November, pp. 537–553

**Service de la Statistique Général de France [1878]**; *Annuaire Statistique de la France* (Imprimerie Nationale, Paris)

**Tackett, Timothy [1986]**; *Religion, Revolution, and Regional Culture in Eighteenth-Century France: The Ecclesiastical Oath of 1791* (Princeton University Press, Princeton)

**Tackett, Timothy [2006]**; 'The French Revolution and religion to 1794', in S. J. Brown and T. Tackett [2006]; *The Cambridge History of Christianity – Volume VII: Enlightenment, Reawakening and Revolution 1660–1815* (Cambridge University Press, Cambridge), pp. 536–555

**Tesfatsion, Leigh [2005]**; 'Agent-Based Computational Economics: A Constructive Approach to Economic Theory', in K. Judd and L. Tesfatsion (Eds.) [2005]; *Handbook of Computational Economics - Volume 2: Agent-Based Computational Economics* (Elsevier/North-Holland, Amsterdam), pp. 831–880

**Van de Walle, Etienne [1974]**; *The Female Population of France in the Nineteenth Century* (Princeton University Press, Princeton)

**Van de Walle, Etienne [1976]**; 'Alone in Europe: The French fertility decline until 1850', in Tilly, Charles (Ed.) [1976]; *Historical Studies of Changing Fertility* (Princeton University Press, Princeton), pp. 257–288

**Van de Walle, Etienne and Helmut V. Muhsam [1995]**; 'Fatal Secrets and the French Fertility Transition', *Population and Development Review,* Vol. 21, No. 2, pp. 261–279

**Weir, David R. [1983]**; 'Fertility Transition in Rural France, 1740–1829', PhD dissertation, Stanford University.

**Weir, David R. [1994]**; 'New Estimates of Nuptiality and Marital Fertility in France, 1740–1911', *Population Studies*, Vol. 48, pp. 307–331

**Wrigley, E. Anthony [1985]**; 'The Fall of Marital Fertility in Nineteenth-Century France: Exemplar or Exception? (Part II)', *European Journal of Population*, Vol. 1, No. 2–3, pp. 141–177

**Wrigley, E. Anthony and Roger S. Schofield [1981]**; *The Population History of England 1541–1871 – A Reconstruction* (Cambridge University Press, Cambridge)

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