Bureau d'économie théorique et appliquée (BETA)
UMR 7522

Documents de travail

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Document de Travail n° 2016 – 42

Octobre 2016

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Economic and Demographic Interactions in Post-World War France: A Gendered Approach[1]

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Abstract

This paper investigates the interaction between economic, demographic and educational variables in post-World War II France. Based on the assumptions of the unified growth theory, we estimate a vector auto-regression for data on fertility, GDP per capita, educational attainment, labor force participation and wages over the period 1962-2008. The methodology employed is based on VAR modeling, using a non-structural approaches. Our findings are consistent with the statements of the theoretical literature and emphasize the importance of the role played by gender roles on demographic and economic developments. In particular, the analysis shows that relative wages endogenously adjust to the level of female education and fertility. The investigation of the effect of shocks through the analysis of impulse responses confirms these results.

JEL Classification: C32, J16, N34

Keywords: Causality • Vector Auto-regression • Gender • Economic Growth • France

[1] We thank Jamel Trabelsi and Michael Hauper for their useful comments on a previous version of this paper. The responsibility of the final version remains, of course, with the authors.

1. Introduction

The recent literature on unified growth theory has emphasized the importance of understanding the development process as a whole. First advanced by Galor and Weil (1999, 2000),[2] unified theories of growth model the transition from Malthusian stagnation to modern economic growth in a single framework. According to the authors, the reversal in the causal relationship between output and population growth marked the transition to Modern Growth. The substitution of the children quantity by children quality – common to most unified models – is a fundamental mechanism underpinning the development process. According to the theory, the rise in the rate of technological progress (through the emergence of new technologies) during the process of industrialization increased the demand for human capital and induced parents to invest more in the education of their offspring. Investing in education increasing the opportunity cost of having children, parents would have had to choose between the number and the education of their children. This is the so-called child quantity-quality (Q-Q) trade-off.[3] This process eventually triggered the demographic transition, which has been shown to play a central role in the transition to sustained economic growth.

Various studies have recently attempted to test the hypotheses of the unified growth theory (Galor and Weil, 2000) and its developments (see Galor, 2005). Most papers focused on pre-industrial societies (period for which the theory predicts a positive association between fertility and income). Recent papers applied a structural model in order to analyze the Malthusian mechanisms. This is notably the case of Lee and Anderson (2002) for pre-industrial England (1541-1870), repeated by Crafts and Mills (2009) using Clark's wage series. Nicolini (2007) also studied the relationship between birth rates, death rates and real wages for England (1541-1841). All came to the conclusion that the Malthusian equilibrium did not exist in pre-industrial England.

Surprisingly, there exists little evidence on the association between income growth and fertility change in modern times (Modern Growth phase). As a complement to existing literature using VAR modeling, we explore the validity of the theoretical predictions underlining the third stage of the development process (Modern Growth) and the origins of sustained economic growth. Furthermore, we investigate a novel perspective by exploring the question from a gender perspective. Few theoretical models emphasize the importance of the role played by gender equality and/or female empowerment on both demographic and economic transitions, among them are Galor and Weil (1996), Lagerlöf (2003) and Diebolt and Perrin (2013a, 2013b). How well do mechanisms described in these models fit the observed patterns in post-WWII France? To what extent an observable fertility change should be seen as a response to a preceding change of income, educational attainment and/or gender relations? To tackle these questions, we empirically investigate the

[2] The seminal work of Galor and Weil was quickly followed by new contributions; for example, Jones (2001), Lucas (2002), Hansen and Prescott (2002), Galor and Moav (2002), Doepke (2004), Galor (2005), Strulik and Weisdorf (2008), among others.

[3] Becker (1960) was the first to introduce the distinction between child quantity and child quality, followed by Becker and Lewis (1973) and Willis (1973).

interactions between gender empowerment, economic, demographic and educational evolutions during the Modern Growth Regime.

Demographic and economic data are likely to be intrinsically endogenous. In order to study their interactions, we use a vector auto-regressions method (VAR).[4] The model is applied to French data for the 1962-2008 periods. It includes series on demographic, socio-economic and educational data: fertility rates, GDP per capita (as a proxy for technological change and productivity growth), wages, labor force participation, enrollment rates in higher education and measures of gender equality. This time period captures certainly one, if not the most, fundamental upheaval in women's life, i.e. the sexual and cultural revolutions (Goldin, 2006), and is accordingly a critical period to study and test the interaction between gender equality and demographic and economic transition. The VAR methodology gives the possibility to distinguish the exogenous and endogenous components of the interactions. This aspect is crucial to the analysis conducted below. The relationships are investigated relying on a non-structural analysis based on the Granger causality relationships.

The paper is structured as follows. Section 2 presents the theoretical background of dynamic interactions between economic, demographic and educational variables. Section 3 describes the data and discusses the identification strategy. The methodological framework is detailed in the section 4 and the results of the estimations are presented in section 5. Finally, the last section concludes by summarizing our main findings.

2. Theoretical Background and Testable Hypothesis

One basic challenge of unified theories of growth is to explain the transition over time from a positive association between income and fertility to a negative association. A few theoretical models involve the impact of gender equality and female empowerment (Galor and Weil, 1996; Lagerlöf, 2003; Diebolt and Perrin, 2013a, 2013b).

The literature on the long-run relationship between gender relations, demographic change and economic growth remains scarce. Galor and Weil (1996) are the first to introduce gender aspects in a growth model. In their paper, the authors investigate a new mechanism linking growth and fertility, and notably the role played by the decline in the gender wage gap in the onset of the demographic transition. They argue that technological progress (along with the process of industrialization) increased the relative wages of women. In particular, they explain how the rise in the demand for women's labor played positively on the decline in the gender wage gap during the industrialization and how this process ultimately triggered to demographic transition. The three main elements of the model are the following ones: *(i)* the analysis of fertility in terms of

[4] In such models, each equation describes the evolution of a variable in function of its own lagged values and of the lagged values of the other variables of the system.

men's and women's relative wages; *(ii)* the effect of the population growth on the level of capital per worker; *(iii)* increase in the capital intensity of the economy raises the relative wages of women. One of the key ingredients of the model is the negative correlation between women's relative wages and fertility by increasing the opportunity cost of having children. According to the authors, this creates a positive feedback loop that generates both a demographic transition and accelerated output growth. As long as women do not participate to the labor force the level of output growth remains low and fertility high. Once the capital stock becomes sufficiently high, women's wage increases both the labor force and the output growth increase and fertility decline. Therefore, a rise in women's wage has two opposite effects: a positive effect inducing an increase in the number of children (income effect) and a negative effect on the cost of raising children triggering to a decline in the offspring (substitution effect). Since the substitution effect dominates it generates a rise in the female labor force participation and a decline in fertility. We observe two steady-states: a low steady state characterized by low output and capital per worker, low female-to-male wage and high fertility and a high stable steady-state with high output and capital per worker, high women's relative wages and low fertility.

Lagerlöf (2003) construct a unified theory of economic and demographic long-run development. In this paper, Lagerlöf suppose the existence of discrimination from parents toward daughters' education and postulates that the onset of economic growth is linked with the increasing equality in income and power between men. In this model, exogenous increases in female human capital are at the origin of the substitution of quantity for quality of children.

Diebolt and Perrin (2013b), contrary to Lagerlöf, consider individuals investing in their own education and take the evolution of gender equality as being endogenously linked with the evolution of the relative distribution of human capital within the members of the household. The substitution from quantity to quality of children derives directly from changes in gender relations. As women become more equal to men (notably in terms of human capital), their time becomes more expensive, fertility then fall while per capita income increases. The relationship between fertility and income changes from positive to negative as far as gender equality increases – as the economy evolves from post-Malthusian stagnation to sustained economic growth. Underlining mechanisms describe an evolution from a dominance of the income effect towards the supremacy of the substitution effect. Therefore, we should observe a transition from growing population with per capita income since gender equality is low to a decline in population growth as far as gender equality, and then per capita income, keep on increasing. In this model, the transition from stagnation to sustained growth is observed in parallel to gender empowerment.

Hence the models predict the existence of positive interactions between women's relative wage and female labor force participation and between income and female labor force. They also predict the existence of negative interactions between female labor force participation and fertility in later stage of development. In addition, Diebolt and Perrin (2013b) suggest a key role played by parental education on fertility. We want to test here the validity of some of the assumptions and predictions of these models; and notably to address the question of the relative impact of female and male education on the workforce and on fertility. In particular, we test the existence of positive interactions between female education and female labor force participation (Goldin, 2006; Diebolt and Perrin, 2013a, 2013b), between wage and labor force participation (Goldin, 2006), and the negative interaction between female education and fertility (Diebolt and Perrin, 2013a, 2013b). In other words, we aim at examining the existence of income and substitution effects in France over the period 1950-2008. What role has been played by the changes in gender relations on demographic and economic variables?

3. Data and Stylized Facts

The methodology used in this paper is designed to focus on long term interactions among and between demographic and economic aggregates. We use annual series to track the causal relationships that may have impacted the evolution of demographic, economic and educational variables in France during the second half of the 20th century.

3.1. The Data

The use of modern data enables us to capture the impact of the probable strongest upheaval that occurred in the history of gender relation. Goldin (2006) emphasizes the existence of four main phases in the emergence of women modern economic role in the United-States during the 20th century. The first phase (end 19th century – 1920) is the one of independent female workers. Women are poorly educated (less than the average population). Young and unmarried women participate in the labor market and excite the workforce at marriage. Goldin argues that during this phase, the income effect[5] was higher than the substitution effect.[6] During phase 2, ranging from the 1930s to 1950, we note an easing on the constraints in married women's work. As a result, the labor force participation of married women substantially increases, as well as high school enrollment rates. The income effect begins to decline. In parallel, the substitution effect substantial increases. The third phase (1950-1970) sets up the roots of the revolution. Goldin observes a continuous increase of married women labor force participation – more responsive to changes in wages. The income effect continues its decline with the increase in female education. And for the first time, the substitution effect becomes more important than the income effect. According to Mincer (1962), as real incomes rose, the female labor force participation increases even if the increase in female earnings relative to that of men is rather slight. Finally,

[5] The income effect reveals the change in child quantity demanded brought about by a change in income. So that, any increase in income should increases the quantity of children demanded by households.
[6] The substitution effect is observed with changes in relative price of goods such that an increase in income will induce individuals to have fewer children but better educated ones.

phase 4 – going from late 1970s to the present – is called by Goldin: the “quiet revolution”. This period witness an important increase of female investments in higher education (college – graduate). The change from income to substitution effect illustrates fundamental transformation of women’s role during the 20th century (Goldin, 2006).

The last quarter of the 20th century has been particularly rich from a gendered perspective. Dramatic event changed women’s life and more generally gender relations; among them: the development of the contraceptive Pill (by Gregory Pincus in 1956 and its commercialization), the foundation the same year of the *Mouvement Français pour le Planning Familial* (MFPF)[7], the Neuwirth legislation authorizing the use of contraceptives in 1967 or the Veil legislation legalizing abortions in 1975. The roots of the revolution that transformed women’s employment, education and family (see Goldin, 2006) took place at that period in most Western countries.

> “*Expectations regarding future work, social norms concerning women’s family and career, and factors accounting for women’s life satisfaction began to change in the late 1960s and 1970s.*” (Goldin, 2006)

Demographic data are measured by the fertility rates; economic data by the GDP per capita and the net yearly wages; and educational data by the enrollment rates in higher education. These data are taken from diverse sources. Most series are available for the whole 20th century, such as the GDP per capita and the fertility rates. Nonetheless, in order to avoid war and inter-war periods (highly volatile periods), we first choose to restrict our study to the second half of the 20th century in France (1950-2008). However, the series requiring a distinction by gender are however not so easily available. This is notably the case of the labor force participation that is only available by gender over the period 1962-2008. To explore whether demographic and economic interactions follow a stable pattern and to be able to integrate more variables, we finally investigate the sample 1962-2008.

The GDP per capita, as a measure of living standard, is taken from Maddison (2008) database. The fertility rate – that consists in the number of births per thousand people – has been constructed using data from the *Institut National de la Statistique et des Études Économiques* (INSEE). Other series are not so easily available on the entire period and required interpolating missing values (across several gaps) to obtain uninterrupted annual series. The female-to-male wage ratio is constructed using the data of male and female annual average wages from the INSEE. In order to account for changes in the skill composition of the population, we use series on educational attainment. We distinguish two measures for education: the stock of education by gender – measured by the number of students in higher education; and the gender gap in education. The first variable is built up by taking the ratio between the number of males and females enrolled in higher education (all years combined) and the total population. These two series are respectively called male higher education and female higher education. The second variable consists simply in the female-to-male enrolment in higher education.

[7] French Movement for Family Planning

Data on the labor force participation are taken from the INSEE. The data are only available from 1962. These variables allow us to measure the gender composition of the labor force and consist in the ratio between women (and men) labor force and the total female (male) population – aged 15 and more, in percent. In addition, we create a series measuring the gender gap in paid labor activities by taking the ratio between female and male labor force participation.

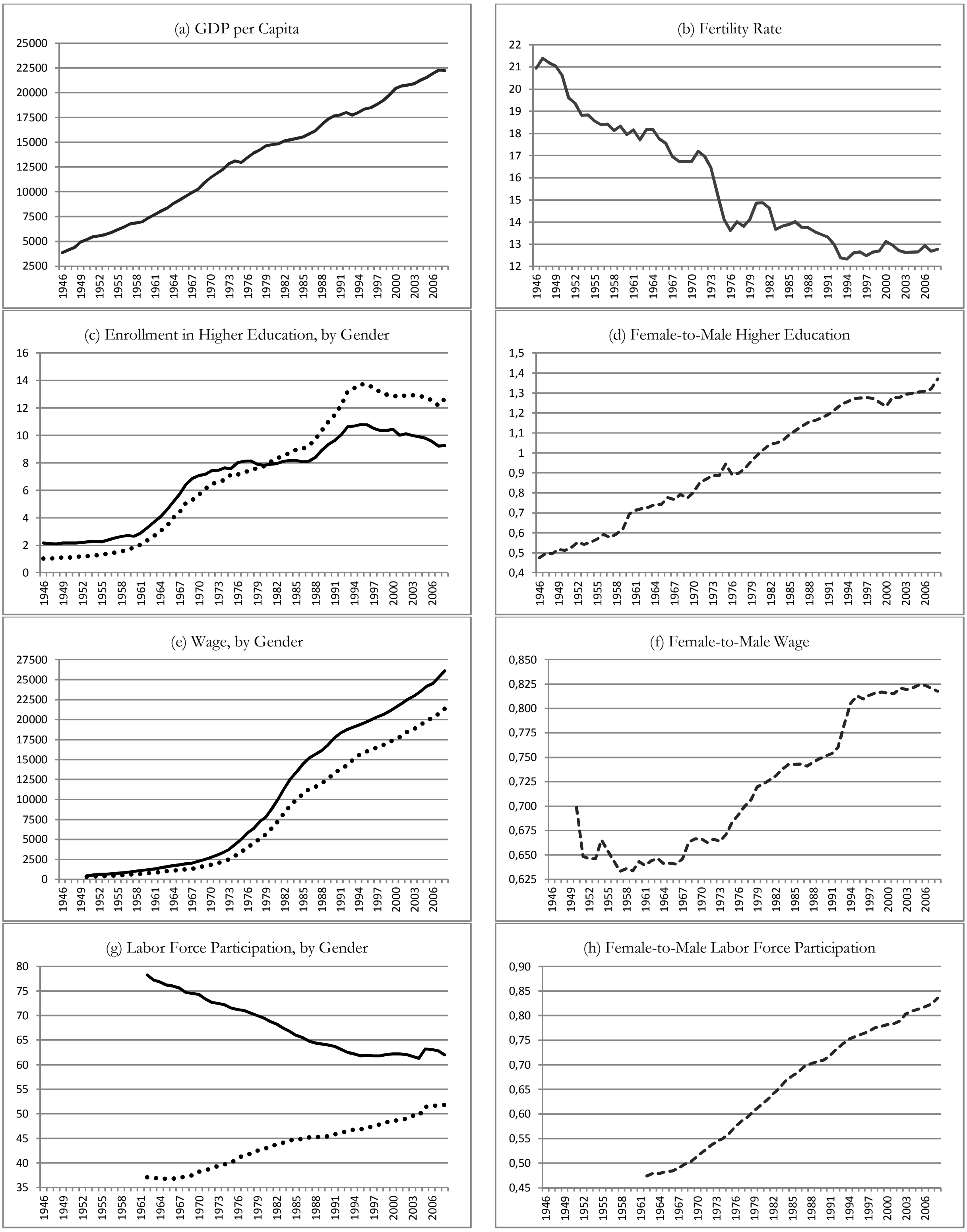
3.2. The Stylized Facts

The series are depicted in Figure 1. The figure offers a broad picture of the French economic and demographic experience in the aftermath of World War II. The first evidence raised by the graphs is the inverse evolution of economic and demographic data. As shown in greater detail in Figure 1a, the GDP per capita increased constantly – from 3 855 in 1946 to 22 223 in 2008. On the opposite way, fertility rates (Figure 1b) declined from 20.9 children per thousand people in 1946 to 12.7 in 2008 – with a sharper decline observed in the seventies and a balanced path since the mid-1990s. In association with demographic and economic evolutions, we note profound changes in the skill-composition of the population. Figure 1c highlights the evolution of enrollment rates in higher education by gender. We observe a strong increase in the pace of students enrolled in higher education for both genders from the beginning of the sixties. The curve of females' enrollment overshoot that of males at the end of the seventies while the share of male students stabilizes, before increasing again from the end of the eighties. However, the number of male students never caught up back that of females. Additionally, both men and women wages increased at a significant pace from the beginning of the seventies – always at a higher level in the case of men (Figure 1e). However, male and female paid labor activities evolved in the opposite direction. While the share of men within the labor force participation decreased constantly over the studied periods (1962-2008), that of women continued to rise on the same period (see Figure 1g).

Concurrently to economic, demographic and educational evolutions, drastic changes occurred on the gender side. Figures 1d, 1f, and 1h illustrate the evolution of gender relations during the second half of the 20th century. More precisely, these figures show a catch-up of women in terms of education, wage, and labor force participation that took place during the second half of the 20th century. It can be clearly seen from Figures 1f and 1h that the catch-up reinforced from the end of the sixties-beginning of the seventies in terms of wage[8] and paid labor, while the increase was rather constant and happened earlier in higher education (Figure 1d). Indeed, regarding higher education, the ratio increased from 0.47 to 1.37 between 1946 and 2008. In terms of wages and labor activities, the ratio increased from 0.64 to 0.82 and from 0.47 to 0.83, respectively, over the period 1962-2008.

[8] We observe a slight decline in terms of wage gap at the beginning of the period (just after 1946) – and a stay at its lowest rates during the fifties and the sixties – that is due to women return in the domestic sphere at the end of Second World War.

Figure 1: Stylized Facts of French Economic, Demographic, Socio-Cultural and Educational Variables, 1946-2008



Notes: Data on GDP per capita *(a)* are measured in thousand International GK dollars (Geary-Khamis) base 1990. The fertility rate *(b)* is the number of birth per thousand people. The level of education *(c)* is measured by the number of individuals enrolled in College, all years combined, over total population (dashed line for women, same for Figure e and g). Net yearly wage *(e)* is expressed in euros. The female (male) labor force participation *(g)* is the share of active women (men) over the whole female (male) population in working age (in percent). Female-to-male ratio *(d)*, *(f)*, *(h)* is between 0 and 1 – measuring respectively perfect gender inequality and perfect gender equality.

In the early 20th century, France witnessed an increase in the share of housewives in parallel to the resurgence of patriarchal ideology. French data highlight a decline in the female labor force participation, more pronounced for married women, in relation with the development of manufacturing production processes and the emergence of new technologies allowing for higher labor productivity. The data on female labor force participation show a sharp decline in the share of working women as well as the worsening of the gender occupational gap (see Perrin, 2013). Nonetheless, women's human capital continued to increase but the investments occurred mainly off the job.

One has to wait the second half of the 20th century to note a positive impact of girl's educational investments on better employment opportunities for women. Together with women's autonomy as civil individuals, the access to skilled jobs contributed to deep structural changes in gender relations. The following step towards full emancipation relates to the effectiveness of birth control. With the development of the contraceptive pill (and changing attitude toward women), new job opportunities became available for them since they could also implement new strategies notably in terms of educational investments. The increase in female educational investments raised the number of women in skilled occupations and contributed to reduce gender differences and discriminations in employment and wages. Such deep changes are observed from the middle of the sixties. Measures of female-to-male ratios in labor force participation, earnings, and educational investments in higher education, all suggest that a "quiet revolution" occurred in France as well.

The time of schooling has to be managed simultaneously to that of professionalization and the project of having children (Langevin, 1984). This pattern implied that women had to elaborate strategies to reconcile professional and family roles (Commaille, 1992). Women had to face a trade-off between giving priority to their professional career, delay childbearing, and have more chances to get a stable job, and giving priority to the family life and certainly renounce to work on the labor market (Pailhé and Solaz, 2007) or to work on part time jobs. Between 1975 and 2008, the female labor force increases for all age groups, except for the 12-24 because of the increase in schooling. With more accurate expectations, girls could better prepare their educational investments. At the same time, the female average wage improved strongly, at an increasingly rate from the eighties, thanks to a better training of girls and due to the generalization of stable jobs.

4. Methodology – Non-structural VAR Analysis

In order to explore the relationship between economic and demographic variables, we use a VAR approach – introduced into the historical-demographic research by Eckstein et al. (1984).[9] Various contributions rely on VAR models to analyze economic and demographic relationships (see for instance Hondroyiannis and Papapetrou, 2002; Nicolini, 2007; Craft and Mills, 2009).[10] Our analysis explores the non-structural relationships – accounting for Granger's causality links – between economic and demographic variables.

4.1. Preliminary Tests

The Granger's causality requires to work within the framework of non-structural VAR. A VAR modeling can be written as:

(1) $$X_t = \sum_{i=1}^{p} A_i X_{t-1} + \varepsilon_t \quad \Leftrightarrow \quad \Phi(\mathrm{L})\, X_t = \varepsilon_t,$$

Where, X_t is a $(n \times 1)$ vector of variables, A_i is a $(n \times n)$ matrix, p is the optimal lag of the model,[11] and ε_t is a $(n \times 1)$ vector of innovations /residuals. $E(\varepsilon_t {\varepsilon'}_t) = \Sigma$ is a symmetric positive $(n \times n)$ matrix. $\Phi(L) = \left(L - \Phi_1 L - \Phi_2 L^2 - \cdots - \Phi_p L^p\right)$ is a polynomial lag operator as $L^k \mathrm{X}_k = X_{t-k}$.

The use of this type of model requires beforehand to test for various assumptions. First of all, it is necessary to work with stationary variables.[12] Therefore, we use the unit root test of Elliott et al. (1996) – considered more efficient (Salanié, 1999) than the classic test of Dickey-Fuller (1979) – to determine the order of integration for all the series. Once variables are stationary, we select the optimal number of lags – that needs to be sufficiently large for residuals to become white noise. Several criteria contribute to determine optimal lags. All of them are based on the maximization of the log-likelihood function. Next, we proceed to the bivariate/multivariate cointegration analysis. The presence of cointegration relationship(s) has then to be tested (Engle and Granger, 1987; 1991).[13] To do so, we use the Johansen test (1988). Variables are said to be cointegrated if they exhibit long-run stable relationship(s), namely if they share common trends. The presence

[9] "The methodology of vector auto-regression appears useful for studying historical series on climatic, economic and demographic variables where we do not yet have a sufficient theoretical foundation for specifying and estimating structural models", p. 295.

[10] Craft and Mill (2009) also used a structural modeling.

[11] There are several criteria to determine the optimal lag of a VAR modeling (Akaike, 1974; Schwartz, 1978; Hannan-Quinn, 1979), based on the maximization of the logarithm of the log-likelihood function. Here, the optimal lag of the model is the one which satisfies most criteria.

[12] A X_t process is known as stationary if all its moments are invariants for any change of the origin of time. There are two types of non-stationary processes: the TS processes (Trend Stationary Processes) which present non-stationarity of the deterministic type and the DS processes (Difference Stationary Processes) for which non-stationarity is due to a random type. These processes are respectively stationarized by a deviation from the deterministic trend and with a differences filter. In this last case, the number of filters indicates the order of integration of the variable. A variable is integrated of order "D" if it is necessary to differentiate it "D" times to make it stationary.

[13] A necessary condition of cointegration between two series X and Y is that they have the same order of integration.

of cointegration needs to be corrected (Vector Error Correction Model) in order to avoid any problem of fallacious regressions (Granger and Newbold, 1976).[14]

4.2. Granger Causality

The detection of Granger causal relationships allows for a better understanding of economic, demographic and educational phenomena, but may also contribute to provide better economic policies. There are two approaches of causality (Granger, 1969; Sims, 1975), which are generally equivalent (Bruneau, 1996).[15] We choose here a Granger test (1969) as we consider the potential relationships between economic and demographic variables not depending on a stochastic context.[16]

To study the direction and sign of causality, we investigate how our variable of interest reacts when a change occur on the second variable. Considering a two-variable model, Equation (1) can be written as follows:

(2) $$\begin{bmatrix} X_t \\ Y_t \end{bmatrix} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \begin{bmatrix} X_{t-1} \\ Y_{t-1} \end{bmatrix} + \begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} \begin{bmatrix} X_{t-2} \\ Y_{t-2} \end{bmatrix} + \cdots + \begin{bmatrix} A_p & B_p \\ C_p & D_p \end{bmatrix} \begin{bmatrix} X_{t-p} \\ Y_{t-p} \end{bmatrix} + [\varepsilon_t]$$

Then, for a causal relationship going from variable X to variable Y, the sign of this relationship is determined by the sign of the following ratio:

(3) $$\sigma_{X \to Y} = \frac{\sum_{i=1}^{p} B_i}{1 - \sum_{i=1}^{p} A_i},$$

4.3. Dynamic Analysis

Finally, we explore the dynamic relationship linking our variables of interest. The dynamic analysis consists in studying the effects of exogenous variables on the endogenous ones. Although VAR models consider all the variables exogenous and/or endogenous, the dynamic analysis requires considering innovations as exogenous variables. The simulation of shocks on innovations for each variable helps us to understand how (impulse response function) and to what extent/proportion (variance decomposition) others variables are impacted. In other words, we observe how a simulated shock on the innovation of the variable X affects the variable Y.

[14] If two variables are cointegrated, the good statistic quality of the model comes from the presence of a common stable trend in the long run between variables; the use of the model is not reliable and it is necessary to remove this common trend before the causality and dynamic analysis.

[15] Granger causality relates to the propagation of deterministic impulses such as structural changes. On the contrary, Sims analysis is based on the propagation of stochastic impulses representative of "surprises".

[16] The definition of causality is given by Granger (1969): the variable X causes the variable Y if the prediction of Y is improved when one incorporates information concerning X and its past into the analysis.

Formally, the dynamic analysis consists in studying the residual part of equation 1. The right-hand part of the equation represents the "infinite moving average" of the VAR modeling, VMA (∞); where M_i is the matrix of impact multipliers and $M_0 = I_n$. Thus, a shock which affects the innovation ε_t at time t will be reflected in all future values of X through M_i.

(4) $$\Phi(L)X_t = \varepsilon_t \quad \Leftrightarrow \quad X_t = \Phi^{-1}(L)\varepsilon_t = \Psi(L)\varepsilon_t = \sum_{i=0}^{\infty} M_i \varepsilon_{t-i},$$

Where $\sum$ represents the variance-covariance matrix.

We apply the Choleski decomposition to $\sum \ = PP^{-1}$, where P is an upper triangular matrix with positive diagonal elements. Thus equation (4) becomes:

(5) $$X_t = \sum_{i=0}^{\infty} C_i P P^{-1} \varepsilon_{t-i} = \sum_{i=0}^{\infty} \Psi_i \, u_{t-i}$$

With $\Psi_i = C_i P$ and $u_{t-i} = P^{-1}\varepsilon_{t-i}$.

The variance-covariance matrix of u_t equals the identity matrix and Ψ_i represents the response of the system after i period – following a normalized and independent shock on the innovation. The simulation of shocks allows us to analyze the direction and the intensity of their repercussions and impacts.

Non-structural VAR models present the advantage to take into account the intrinsic structure of the series and the dynamical effects between variables, offering more reliable analyses at the dynamical level than traditional models.[17] They also offer the possibility to consider all causal relationships between variables without *a priori* on their potential exogeneity.[18]

5. Socio-economic and Demographic Interactions

5.1. Granger Analysis

In order to test the unit root hypothesis, we apply the Elliott et al. (1996) test. Over the period 1962-2008, all variables are stationary in first difference, to the exception of the GDP per capita and the female enrollment rates in higher education that are both a combination of DS and TS processes (see Table A.1. in Appendix). Before testing the causal relationships, we determine the number of delays necessary for the model (i.e. the

[17] The intrinsic structure of the series is related to its identification in the ARIMA classification (Box and Jenkins, 1976).
[18] Non-structural VAR models are sometimes criticized for requiring to include in the model a number of variables matching the degree of freedom in order to avoid estimation problems (Johnston, 1999), and for the lack of theory on which they rely.

order of the VAR). The lags are optimally selected for each period according to a set of five criteria (Table A.2. in Appendix).[19]

Next, we test the presence of multilevel cointegration to avoid any problem of fallacious regressions (Granger and Newbold, 1976). To do so, we use the Johansen (1988) procedure. Detailed results are presented in the Table A.3 in Appendix. Two variables are said to be cointegrated if they share a common trend. The Johansen test shows the absence of cointegration (namely no long-run stable equilibrium relationships) between all variables – to the exception of the relationship between male higher education and female-to-male wage ratio; and between male higher education and GDP per capita.

Table 1: Summary of the Global Causality Analysis

Relationships	Sign
GDP per capita → Female higher education	+
GDP per capita → Female-to-male labor force	-
Fertility rate → Female-to-male labor force	-
Fertility rate → Wage ratio	-
Female higher education → Wage ratio	+
Wage ratio → Fertility rate	+

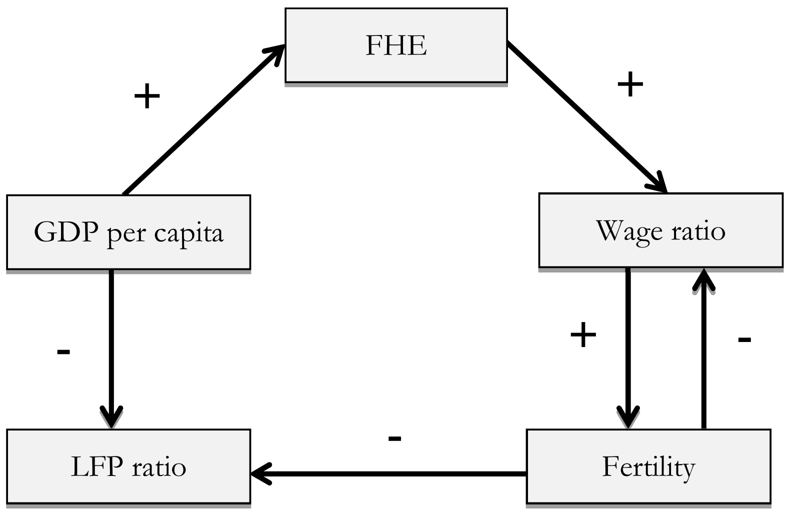
Note: Detailed results are given in Appendix D.

The results of the multiple Granger Causality analysis are summarized in Table 1 (detailed results are provided in Appendix, see Table A.4). The Granger causality tests emphasize the existence of six causal relationships over the 1962-2008 periods. Figure 2 displays the causal loop resulting from the multiple Granger causality test using socio-economic and demographic data. The first relationship links the GDP per capita and the female higher education. The analysis depicts a negative relationship that goes from the GDP per capita to the share of females enrolled in higher education. This causal relation suggests that a higher wealth in the economy generates an increase in the number of females enrolled in higher education. The direction of causality can be interpreted as a strategy of innovation (Aghion and Cohen, 2003): the level of economic growth is such that it conditions the organization and the development of higher education,

[19] Likelihood Ratio (LR), Final Prediction Error (FPE), Akaike Information Criterion (AIC), Hannan–Quinn (HQ) and Schwartz (SC) criteria. Detailed results are given in Appendix A.2.

especially that of girls. In this case, higher education can be apprehended as an infrastructure investment (Diebolt, 2000). Education then becomes a condition for the effectiveness of material means.

Figure 2: Causal Loop of Economic and Demographic Interactions, 1962-2008



We observe three strong causal relationship linking fertility to market activities. First, the Granger tests indicate the existence of a negative causal relationship ranging from fertility to female-to-male labor activity. This new relationship tells us that increased numbers of children per thousand people reduces women activity comparatively to that of men. On the opposite way, a decline in fertility would improve/favor women activity relatively to that of men and therefore would decline gender inequality in terms of paid labor. Second, Granger test highlights the existence of a retroactive loop linking fertility and wage ratio. On the one hand, the wage ratio has a positive influence on fertility: an increase (resp. decrease) in female wage relatively to that of males (female-to-male wages – gender equality in terms of wage) rises (resp. reduces) fertility. This is the income effect, i.e. higher income increases fertility (Becker, 1960). On the other hand, fertility has a negative influence on the wage ratio. This dual relationship emphasizes the importance of the role played by fertility on the labor market, and more precisely on wages. This means that a decline (resp. increase) in fertility rises (resp. reduces) women wages relatively to that of men. This is the substitution effect. As already suggested by theoretical models, we empirically observe a combination of income and substitution effects. More equal wages between genders (namely, higher females incomes regarding to that of males) allows households to have and to rear more children. Instead, higher fertility tends to deteriorate female wages relatively to male wages.

In other words, the fertility decline observed during the second half of the 20th century would have contributed to increase women income relatively to that of men. Instead, taking men and women wages separately does not show any relationship with fertility. We observe here the expected causality between fertility and female-to-male relative wages. As explained in Galor and Weil (1996), considering that all childrearing is done by women, increases in women's wages raise the price of children (as well as household income) and induces a substitution effect on the demand for children.[20]

We note a positive causal relationship between the number of females enrolled in higher education and the wage ratio. Though, we find that a higher level of female educational investments imply a decrease in the level of wage inequality between men and women. Schultz (1978), Goldin (1990), or Galor and Weil (1996), all reported that industrialization and increase in capital intensity of the economy were responsible for the rise in the relative wages of women. We observe here an additional underlying mechanism, which emphasize the importance of female education in the rise of women's relative wages. This relationship means that the returns from education increase with educational investments. Higher is the time spent by girls to get educated, higher is their expected wage. With the legalization of birth control, women could anticipate more accurately their future working lives. As a consequence, they could better prepare themselves by investing in formal education and could assume positions that involved advancement. Therefore, better and higher female investments in human capital are one possible reason why returns to job experience increased for women relative to men (Goldin, 2006).[21]

The Granger test indicates a negative relationship linking GDP per capita and female-to-male labor force participation. Therefore, contrary to what we were expecting, an increase in the GDP per capita tends to increase the gender gap – in terms of labor force participation. We deduce two main plausible explanations from that result. The first one can find its source in the fact that higher living standards can create a dynamics within the economy that would trigger male labor force participation up relatively to female labor force participation (discrimination in employment). On the opposite way – since GDP per capita decline – we can imagine that women activity will be preferred to that of men due to its lower cost (lower wages).

The relationships between fertility, female higher education and wage ratio suggest the existence of a quantity-quality trade-off over the reference period. We indeed observe a negative relationship between female education and fertility (through the effect played on wage ratio), such that, to allow for improvement in the wage ratio, women need to invest more in higher education but at the same time need to have fewer children. With the legalization of birth control, women can look more peacefully to their future. They can set up a coherent set of independent strategies, activities and investments without the fear of getting pregnant and

[20] Examples of the effect of an increase in women's relative wage on fertility was already highlighted in Butz and Ward (1979) and Heckman and Walter (1990), respectively for US and Sweden.

[21] Institutional improvements such as antidiscrimination laws or governmental interventions can also be one of the reasons explaining the reduction in female-to-male wage gap.

consequently having to pay a high social cost (Goldin and Katz, 2001). This picture allows us to understand the role played by demographic and educational variables on economic variables. It confirms the decisive role played by women and more precisely the key role of women's educational investments.

5.2. Dynamic Analysis

Although the Granger causality analysis gives us indications on the direction of causality among our variables, it does not provide information on the relative strength of the effect of the variables on one another. Hence, as a further step, we run a dynamic analysis. The impulse response analysis indicates the sense of the reaction of a variable after a positive simulated shock on the other variables. Figure 3 depicts the impulse responses of fertility, GDP per capita, female-to-male labor force participation, wage ratio, and female higher education successively. The variance decomposition provides information about the intensity of the relationships (see Table 2). It indicates to what extent the variance of a variable depends on the variation of the others variables.

The GDP per capita appears to have a complete independent evolution (Figure 3a). It appears indifferent to simulated shocks on other variables. Table 2a illustrates this result. The variance decomposition of the GDP per capita depends for more than 95% from its own variations. Figure 3b shows a negative response of female higher education of a positive shock on GDP per capita (blue curve) that becomes positive in period two. The variance of female higher education depends on variations of per capita GDP up to 12% (Table 2b).

Figure 3c highlights the responses of wage ratio to shocks on fertility, GDP per capita, labor force ratio and female higher education. We observe a symmetric positive reaction of wage ratio to shocks on female-to-male labor force participation and female higher education (respectively turquoise and red curves). Instead, we note the opposite reaction for shocks on fertility and GDP per capita (respectively black and blue curves) that impact negatively wage ratio. The two main reactions derive from shocks on female higher education and fertility. Therefore, female higher education affects the variance of wage ratio up to 9% (2.9% for female-to-male labor force) while fertility explains 12% of the variations in wage ratio (19% for per capita GDP) (see Table 2c).

Figure 3d illustrates how fertility reacts to a positive shock on GDP per capita, female-to-male labor force participation, wage ratio, and female higher education. Focusing on the main reactions, we first observe a positive response of fertility of a positive shock on the wage ratio (green curve). The variance of fertility (Table 2d) indeed depends on the variations of the female-to-male wage up to 9% (at 2-year horizon) and 14% (at 5-year horizon). In addition, we note a negative reaction of fertility to a shock in female higher education (red curve). In terms of variance, the variations in fertility are explained for about 5% from the variations in female higher education. The reaction of fertility to a positive shock on GDP per capita takes more time. We graphically observe a positive response that become negative at 3-year horizon (blue curve) – but explaining up to 11% of the variations in fertility.

Finally, Figure 3e presents the responses of the female-to-male labor force participation to a positive shock on the other variables. It results in a negative reaction from a positive shock on GDP per capita (blue curve). The variance of the female-to-male labor force participation depends on the GDP per capita for up to 30% at 5-year horizon (Table 2e).

Figure 3: Impulse Responses

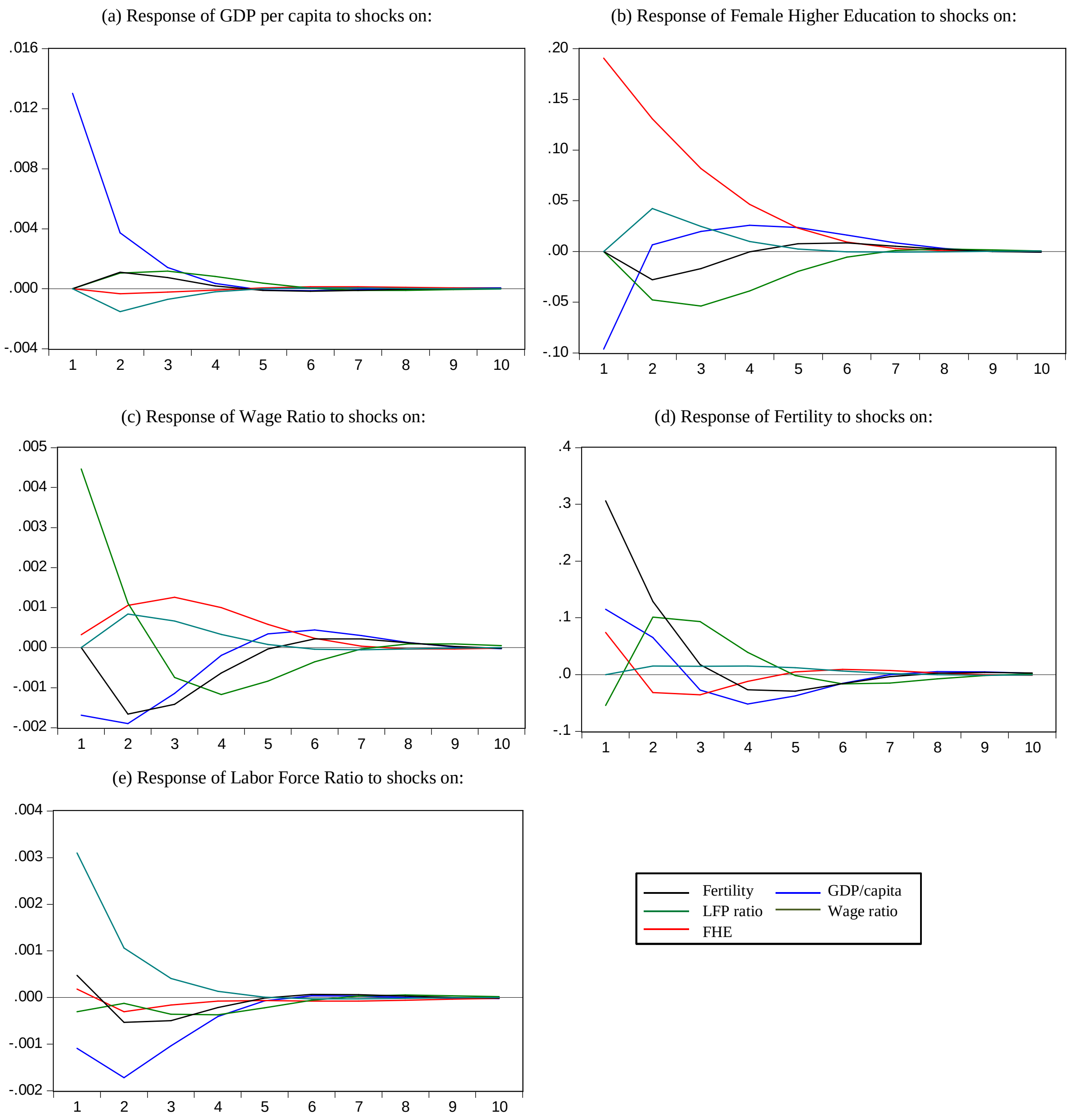


Table 2: Variance Decomposition (Percentage of forecast variance explained by shocks)

(a) Variance Decomposition of GDP/Capita						
Period	S.E.	GDP/capita	FHE	Wage ratio	Fertility	LFP ratio
1	0.01	100	0	0	0	0
2	0.01	97.48	0.06	0.57	0.64	1.25
5	0.01	95.80	0.09	1.68	0.93	1.50
10	0.01	95.73	0.12	1.70	0.95	1.50
(b) Variance Decomposition of FHE						
Period	S.E.	GDP/capita	FHE	Wage ratio	Fertility	LFP ratio
1	0.21	20.29	79.71	0	0	0
2	0.26	13.74	79.08	3.36	1.15	2.67
5	0.29	12.91	74.44	8.35	1.32	2.98
10	0.29	13.22	74.04	8.35	1.44	2.96
(c) Variance Decomposition of Wage ratio						
Period	S.E.	GDP/capita	FHE	Wage ratio	Fertility	LFP ratio
1	0.00	12.40	0.45	87.15	0	0
2	0.01	19.91	3.78	65.61	8.51	2.19
5	0.01	18.68	9.79	56.36	12.20	2.98
10	0.01	19.11	9.78	55.89	12.27	2.95
(d) Variance Decomposition of Fertility						
Period	S.E.	GDP/capita	FHE	Wage ratio	Fertility	LFP ratio
1	0.34	11.46	4.79	2.60	81.16	0.00
2	0.38	11.84	4.42	8.99	74.60	0.15
5	0.41	13.42	4.78	14.12	67.21	0.48
10	0.41	13.48	4.82	14.34	66.85	0.51
(e) Variance Decomposition of LFP						
Period	S.E.	GDP/capita	FHE	Wage ratio	Fertility	LFP ratio
1	0.00	10.64	0.29	0.83	1.99	86.24
2	0.00	26.48	0.80	0.70	3.26	68.77
5	0.00	30.39	0.91	2.40	4.55	61.75
10	0.00	30.33	1.01	2.45	4.60	61.61

6. Conclusion

This paper aims at explaining the interactions between economic, demographic and educational variables, and at testing the validity of the theoretical literature aiming at accounting for the role played by gender equality on economic growth. In this analysis, we focus on the post-World War II period in France. Our analysis explores the relationship linking socio-economic and demographic variables relying on a Granger-causal framework.

The VAR methodology relies on the validation of assumptions. Consequently, we primarily ran unit root tests and Johansen's cointegration tests. Next we investigated the relationship between our variables of interest by analyzing Granger causalities and exploring the variance decompositions. The existence of cointegration confirms that our socio-economic and demographic variables are bound together by common trends and/or long-run equilibrium relationships. The Granger causality analysis emphasizes the existence of six relationships. In particular, it shows the existence of a strong relationship linking fertility to market activities. Furthermore, economic growth appears as a pre-condition to the development of female higher education and contributes to the catch up of the female labor force participation to that of men. Finally, female enrollment in higher education enhances the catch-up of female wages to that of men.

Our results are consistent with several key elements of Galor and Weil (1996) and Diebolt and Perrin (2013a, 2013b), which emphasize the importance of the role played by women in the development process. In particular, the modern phase of the development process, combining both an increase in GDP per capita and a decline in fertility, appears as having been triggered by the increase in gender equality (notably with regards to wage). Another contribution is to show that demographic patterns in France over the period 1962-2008 are explained by the rise in the GDP per capita triggered by higher female educational investments and greater gender equality in terms of relative wage. These results are consistent with theoretical literature showing the importance of considering together the evolution of demographic, economic, educational and socio-cultural variables in order to understand the patterns of development in the Modern growth regime.

The highlighted interactions and more particularly the existence of a substitution effect on the demand for children reflect the fundamental transformation that occurred in women's life and how changes in gender relations changed their view in terms of occupational opportunities. These changes are reflected by improvements in occupation and earning relative to those of men. Further investigations need to be conducted on longer time periods and additional countries in order to check whether these results are consistent across space and time.

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APPENDIX

Table A.1 – Elliot, Rothenberg and Stock (ERS) Unit Root Tests

Variable	Null hypothesis	Included variables in the tested equation	Statistics	Decision
Net rate of Fertility	Unit root	Trend + intercept	-2,57***	DS process
D (Net rate of fertility)	Unit root	Intercept	-3,53***	Stationary
LFP ratio	Unit root	Trend + intercept	-1,59***	DS process
D (LFP ratio)	Unit root	Intercept	-3,78***	Stationary
Wage ratio	Unit root	Trend + intercept	-2,57***	DS process
D (Wage ratio)	Unit root	Intercept	-3,78***	Stationary
LGDP/capita	Unit root	Trend + intercept	-1,03***	DS process
D (LGDP/capita)	Linear trend	Trend + intercept	-4,91***	TS process
SD (LGDP/capita)	Unit root	Intercept	-4,82***	Stationary
HE girls	Unit root	Trend + intercept	-2,08***	DS process
D (HE girls)	Linear trend	Trend + intercept	-3,22***	TS process
SD (HE girls)	Unit root	Intercept	-3,31***	Stationary

Notes: *,**,*** significance at 10%, 5%, 1% respectively; (1) D(variable) means that we consider the first differences of the variable; (2) SD(variable) : means that we consider the variable with a deviation from a linear trend; (3) Unit root test on wage ratio for the period 1950-2008.

Table A.2 – Optimal Lag Selection on the Sample 1962-2008

Variables	Optimal Lag for each criterion					Selected Lag
	LR	FPE	AIC	SC	HQ	
Fertility - GDP/cap	1	1	1	1	1	**1**
Fertility - HE ratio	1	1	1	1	1	**1**
Fertility - HE Girls	1	1	1	1	1	**1**
Fertility - HE Boys	1	1	1	1	1	**1**
GDP/cap - HE ratio	7	1	1	1	1	**1**
GDP/cap - HE girls	1	1	1	1	1	**1**
GDP/cap - HE boys	1	1	1	1	1	**1**
GDP/cap - Wage ratio	1	1	1	1	1	**1**
GDP/cap - Women wage	1	2	2	1	1	**1**
GDP/cap - Men wage	1	1	1	1	1	**1**
Fertility - Wage ratio	1	1	1	1	1	**1**
Fertility - Women wage	1	1	1	1	1	**1**
Fertility - Men wage	6	1	1	1	1	**1**
Wage ratio - HE ratio	1	1	1	1	1	**1**
Wage ratio - HE girls	4	1	1	1	1	**1**
Wage ratio - HE boys	1	1	1	1	1	**1**
HE ratio - Women wage	1	1	1	1	1	**1**
HE ratio - Men wage	1	1	1	1	1	**1**
HE girls - Women wage	1	1	1	1	1	**1**
HE boys - Men wage	5	1	1	1	1	**1**
HE girls - Men wage	1	1	1	1	1	**1**
HE boys - Women wage	1	1	1	1	1	**1**
Fertility - LFP ratio	1	1	1	1	1	**1**
Fertility - Women LFP	1	1	1	1	1	**1**
Fertility - Men LFP	1	1	1	1	1	**1**
GDP/cap - LFP ratio	1	1	1	1	1	**1**
GDP/cap - Women LFP	1	1	1	1	1	**1**
GDP/cap - Men LFP	1	1	1	1	1	**1**
HE ratio - LFP ratio	1	1	1	1	1	**1**
HE ratio - Women LFP	1	1	1	1	1	**1**
HE ratio - Men LFP	1	1	1	1	1	**1**
LFP ratio - HE girls	1	1	1	1	1	**1**
LFP ratio - HE boys	5	6	6	1	1	**1**
Women LFP - HE girls	1	1	1	1	1	**1**
Men LFP - HE boys	1	1	1	1	1	**1**
Women LFP - HE boys	1	1	1	1	1	**1**
Men LFP - HE girls	1	1	1	1	1	**1**
General model*	1	1	1	1	1	**1**

Note: * The general model includes: GDP/cap, HE girls, Wage ratio, LFP ratio and fertility.

Table A.3 – Johansen Cointegration Tests on the Sample 1962-2008

Variables	Hypothesized No. Of CE(s)	Eigenvalue	Trace statistic	Critical Value (5%)	Prob.	Result
Fertility - GDP/cap	0	0.38	31.73	15.49	0.00	**No cointegration**
	1	0.20	10.03	3.84	0.00	
Fertility - HE Ratio	0	0.22	12.57	15.49	0.13	**No cointegration**
	1	0.03	1.33	3.84	0.25	
Fertility - HE girls	0	0.19	12.70	15.49	0.13	**No cointegration**
	1	0.07	3.21	3.84	0.07	
Fertility - HE boys	0	0.20	18.45	15.49	0.02	**No cointegration**
	1	0.17	8.35	3.84	0.00	
GDP/cap - HE ratio	0	0.30	21.44	15.49	0.01	**No cointegration**
	1	0.12	5.66	3.84	0.02	
GDP/cap - HE girls	0	0.26	17.89	15.49	0.02	**No cointegration**
	1	0.09	4.29	3.84	0.04	
GDP/cap - HE Boys	0	0.27	17.30	15.49	0.03	**Cointegration**
	1	0.06	3.01	3.84	0.08	
GDP/cap - Wage ratio	0	0.32	26.28	15.49	0.00	**No cointegration**
	1	0.18	9.13	3.84	0.00	
Fertility - Wage ratio	0	0.19	11.74	15.49	0.17	**No cointegration**
	1	0.05	2.33	3.84	0.13	
Wage ratio - HE ratio	0	0.21	11.71	15.49	0.17	**No cointegration**
	1	0.02	0.87	3.84	0.35	
Wage ratio - HE girls	0	0.22	13.19	15.49	0.11	**No cointegration**
	1	0.04	2.03	3.84	0.15	
Wage ratio - HE boys	0	0.28	18.57	15.49	0.02	**Cointegration**
	1	0.08	3.56	3.84	0.06	
Fertility - LFP ratio	0	0.21	11.35	15.49	0.19	**No cointegration**
	1	0.01	0.63	3.84	0.43	
Fertility - Women LFP	0	0.20	9.90	15.49	0.29	**No cointegration**
	1	0.00	0.04	3.84	0.85	
Fertility - Men LFP	0	0.24	17.16	15.49	0.03	**No cointegration**
	1	0.11	5.05	3.84	0.02	
GDP/cap - LFP ratio	0	0.39	38.48	15.49	0.00	**No cointegration**
	1	0.30	16.29	3.84	0.00	
GDP/Cap - Women LFP	0	0.36	25.72	15.49	0.00	**No cointegration**
	1	0.11	5.32	3.84	0.02	
GDP/Cap - Men LFP	0	0.38	25.44	15.49	0.00	**No cointegration**
	1	0.08	3.98	3.84	0.05	
HE Ratio - LFP ratio	0	0.17	8.31	15.49	0.43	**No cointegration**
	1	0.00	0.17	3.84	0.68	
HE Ratio - Women LFP	0	0.14	6.80	15.49	0.60	**No cointegration**
	1	0.00	0.08	3.84	0.78	
HE Ratio - Men LFP	0	0.11	6.10	15.49	0.68	**No cointegration**
	1	0.02	0.73	3.84	0.39	
LFP ratio - HE Girls	0	0.16	7.81	15.49	0.49	**No cointegration**
	1	0.00	0.18	3.84	0.67	
LFP ratio - HE Boys	0	0.19	12.45	15.49	0.14	**No cointegration**
	1	0.06	2.95	3.84	0.09	
Women LFP - HE girls	0	0.13	6.71	15.49	0.61	**No cointegration**
	1	0.01	0.40	3.84	0.53	
Men LFP - HE boys	0	0.20	14.09	15.49	0.08	**No cointegration**
	1	0.08	3.77	3.84	0.05	
Women LFP - HE boys	0	0.17	11.79	15.49	0.17	**No cointegration**
	1	0.07	3.14	3.84	0.08	
Men LFP - HE girls	0	0.17	11.16	15.49	0.20	**No cointegration**
	1	0.06	2.65	3.84	0.10	

Table A.4 – Pairwise Granger Causality Tests

Null Hypothesis	Obs	F-Statistic	Prob.	Sign
SD HE girls does not Granger Cause SD LGDP/Cap	45	0.036	0.851	
SD LGDP/Cap does not Granger Cause SD HE girls		3.883	**0.055**	+
D Wage ratio does not Granger Cause SD LGDP/Cap	45	0.081	0.778	
SD LGDP/Cap does not Granger Cause D Wage ratio		2.157	0.149	
D Fertility does not Granger Cause SD LGDP/Cap	45	0.471	0.496	
SD LGDP/Cap does not Granger Cause D Fertility		0.016	0.901	
D LFP ratio does not Granger Cause SD LGDP/Cap	45	0.471	0.496	
SD LGDP/Cap does not Granger Cause D LFP ratio		6.411	**0.015**	-
D Wage ratio does not Granger Cause SD HE girls	45	3.323	0.075	
SD HE girls does not Granger Cause D Wage ratio		5.156	**0.028**	+
D Fertility does not Granger Cause SD HE girls	45	0.056	0.814	
SD HE girls does not Granger Cause D Fertility		0.562	0.458	
D LFP ratio does not Granger Cause SD HE girls	45	0.003	0.953	
SD HE girls does not Granger Cause D LFP ratio		0.194	0.662	
D Fertility does not Granger Cause D Wage ratio	45	9.419	**0.004**	-
D Wage ratio does not Granger Cause D Fertility		5.430	**0.025**	+
D LFP ratio does not Granger Cause D Wage ratio	45	1.064	0.308	
D Wage ratio does not Granger Cause D LFP ratio		0.372	0.545	
D LFP ratio does not Granger Cause D Fertility	45	0.901	0.348	
D Fertility does not Granger Cause D LFP ratio		5.425	**0.025**	-