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School Attendance and Skill Premiums in France and the US: A General Equilibrium Approach*

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Abstract

We evaluate the effect of education policies, welfare programmes, technology and demographics on the differential evolution of the skill premium and on the rise in education investment in France and the US. We use a computable general equilibrium model with overlapping generations of individuals and endogenous education decisions. Human capital has two substitutable components – experience and education – both of which evolve endogenously over time. We use an original method to calibrate our model properly on the post-war period and run counterfactual experiments to assess the relative contributions of the different exogenous variables. The expansionary French education policy boosted the supply of skills and kept the skill premium low. In contrast, increasing education costs in the US contributed to increased wage differentials by reducing the rise in

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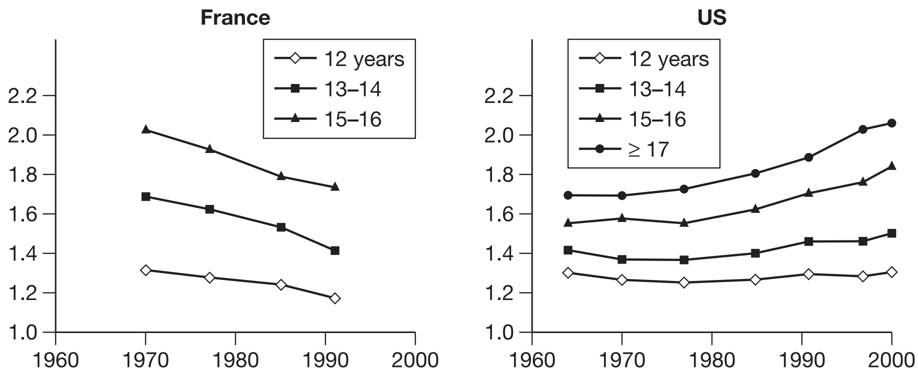
educational attainment. Skill-biased technical change is key to understanding rising school attendance and skill premiums in the US. It has a less important role and appears to be delayed in France.

I. Introduction

During the last three decades, most industrialised countries have experienced a remarkable increase in the educational attainment of their labour forces. The average skill level is expected to increase further in the coming years as younger (and more educated) cohorts progressively replace older (and less educated) ones. In spite of this, returns to skills have also increased substantially in countries such as the US, the UK and, to a lesser extent, Canada. By contrast, in most countries of continental Europe, the skill premium has remained constant or decreased, as in France. This situation is illustrated for the US and French cases in Figure 1, which presents estimates by Wasmer (2001a) of the skill premium for different levels of education. There is a clear difference between France, where the skill premium actually declined, and the US. In contrast, the qualitative pattern of the return to experience is similar in both countries: as reported in Figure 2, it peaked in the 1980s and then declined in both countries. However, the magnitude of the changes is greater in France. Another significant difference between the US and France lies in the investment in education. Appendix B reports the share of time invested in education for the population aged 15 to 24. Education was much higher in the US around 1960, but France caught up and almost reached the US level in 2000. This trend dramatically increased

FIGURE 1

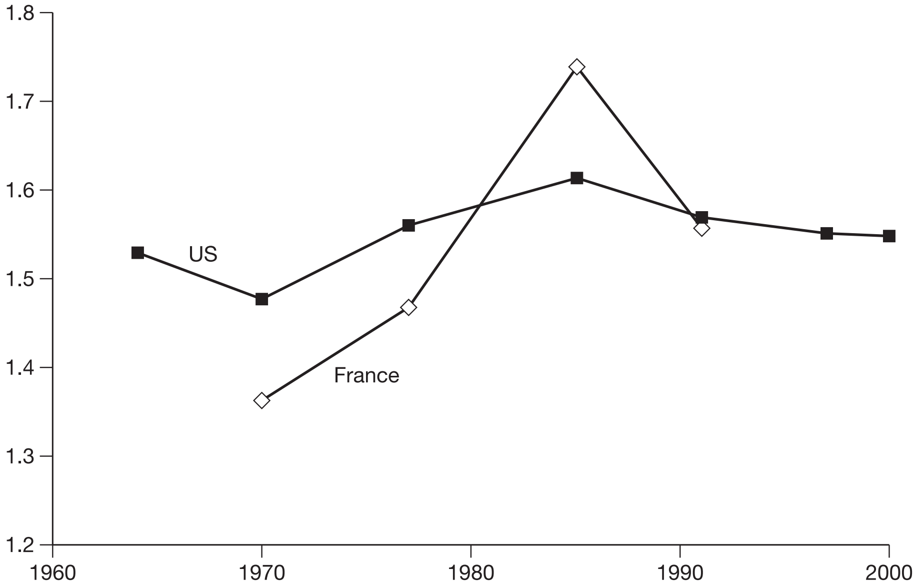
Skill premium in France and the US[a]



[a]The skill premium is calculated as the ratio of the wage associated with x years of schooling over the wage associated with less than 12 years of schooling, holding experience constant, where x = 12, 13–14, 15–16 or ≥17.
Source: Wasmer, 2001a.

FIGURE 2

Experience premium (20 years) in France and the US[a]



[a]The experience premium is calculated as the ratio of the wage associated with 20 years of experience over the wage associated with no experience, holding education constant.
Source: Wasmer, 2001a.

the supply of skills in France and may have reduced the skill premium. Magnac and Thesmar (2002) explain the rise between 1982 and 1993 by a change in French education policy, which increased the chance of students reaching higher levels of education.

Many authors have investigated the causes of rising wage inequality. The literature can be divided into three categories. The first emphasises the role of supply-side mechanisms such as the slowdown in the rate of growth of educational attainment (Card and Lemieux, 2001) and the increased labour market participation of women (Acemoglu, Autor and Lyle, 2004[1]). The second category, supportive of the demand side, puts forward the role of skill-biased technological changes (Katz and Murphy, 1992; Juhn, Murphy and Pierce, 1993; Bound and Johnson, 1992). The last category emphasises the role of institutional changes such as the decline in the real value of the

[1]This paper reveals that increases in female labour supply lower female wages, lower male wages and increase earnings inequality between high-school- and college-educated men. These findings suggest that in the middle of the twentieth century, women were close substitutes to high-school graduates and relatively low-skilled men.

minimum wage, the decline in the unionisation rate and the process of economic deregulation.[2]

All these papers treat changes in educational attainment as exogenous and disregard the important interactions between human capital investment and (actual and expected) returns to skills. The objective of our analysis is to investigate such interactions and to evaluate the relative contribution of (more) exogenous factors – such as public policies,[3] demographic variables, women's participation in the labour market and technical progress – to education choices and skill premiums.

We focus on two countries in which public policies and skill premiums followed contrasting paths – France and the US. Many papers have explained the contrast between France and the US by referring to differences in labour market institutions: in the face of skill-biased technical progress affecting both countries, the US reacted by displaying a higher skill premium while France's minimum wage legislation and/or unemployment insurance prevented unskilled workers' wages from falling (Ljunqvist and Sargent, 1998; Marimon and Zilibotti, 1999). Consequently, unemployment rates increased in France but not in the US. Such a story is, however, not fully convincing. If differences in the flexibility of labour market institutions actually explain diverging paths for the skill premium, we should observe diverging patterns for employment rates (i.e. employment–population ratios) as well. Indeed, faced with similar shocks, employment rates are expected to respond more strongly in less flexible countries. Card, Kramarz and Lemieux (1999) show that the evolution of employment rates across age and education groups in France, Canada and the US is almost identical. We conclude that pure labour market rigidity cannot explain the diverging patterns of education, wage inequality and employment. We will argue that general equilibrium phenomena can explain the diverging patterns without relying on labour market rigidity features.

Consequently, we develop a computable OLG (overlapping generations) model that exhibits several original features, including endogenous education choices. Instead of calibrating our model on hypothetical steady states, we dynamically calibrate it on the post-war period for France and the US, using detailed demographic data, age profiles for taxes and transfers, and observations for educational attainment, retirement age and participation rates. Exogenous processes for technical progress and public policies are identified by letting the model match observed skill premiums and investments in education. To the best of our knowledge, the only computable model endogenising skill formation and wage inequality is due to Heckman, Lochner and Taber (1998). However, they do not simulate their model with

[2]Fortin and Lemieux (1997) argue that about one-third of the increase in male and female wage inequality during the 1980s can be traced to these institutional changes.

[3]That is, education subsidies, welfare programmes, retirement age and taxation.

realistic population scenarios and public policies. Our calibration methodology strongly improves the accuracy and reliability of the results. Hence, our model incorporates many ingredients usually left aside by labour economists and provides new important insights. Practically, we start from the calibrated baseline scenario and run counterfactual experiments to determine the endogenous path for skill premiums and educational attainment when each exogenous variable is kept at its 1960 level. This gives us estimated marginal effects of public policies, technology and demographics on the difference in the observed evolution of the skill premium in France and in the US.

Our analysis reveals that France and the US experience very differentiated demand and supply shocks. Some stylised facts illustrate the magnitude of the supply shocks. The main difference in the population data between France and the US is for the period 2000–50, when ageing is much more pronounced in France. The share of individuals aged 65 and over rises from 18.9 per cent in 1960 to 23.3 per cent in 2000 and 36.6 per cent in 2050 in France; it rises from 16.7 per cent in 1960 to 18.8 per cent in 2000 and 30.2 per cent in 2050 in the US. Ageing can affect current labour market outcomes, through expectations; labour supply will indeed be scarcer in France than in the US, and future wages can thus be expected to be higher. Another difference between the US and France concerns the participation rate of old workers. Figure B2 in Appendix B shows the effective retirement age as computed by Blondal and Scarpetta (1997). The stronger drop in France should have reduced the incentive to accumulate skills, since the productive time for education investment is shortened.

Public policies and skill-biased technical changes have played an important role. Although there are no actual data on the magnitude of these factors, our identification strategy allows us to assess their impact on the French and US economies. We show that the expansionary French education policy boosted the supply of skills and kept the skill premium low. Welfare programmes had a relatively small impact on education choices but a non-negligible effect on the skill premium in France. In contrast, increasing education costs in the US contributed to increased wage differentials by reducing the supply of skills. The skill-biased technical shock appears to be delayed in France and is key to understanding rising school attendance.

The model and its calibration are described in Sections II and III respectively. The results are described in Section IV, while Section V provides a sensitivity analysis of some of our assumptions. Section VI concludes.

II. The model economy

Our model depicts a closed economy with three agents – individuals, firms and the public sector. Individuals are homogeneous[4] within each generation and live a maximum of eight periods of time (i.e. from age 15 to 95), each of them representing 10 years. A detailed and analytical exposition of the model can be found in Appendix A.

1. Demographics

At each date, some individuals die and a new generation appears. Individuals reaching age 15 in year *t* belong to generation *t*. The size of the youngest generation increases over time at an exogenous growth rate.

Each individual lives a maximum of eight periods but faces a cumulative survival probability that decreases with age. The size of each generation changes deterministically through time. However, this decline is attenuated by net immigration.

The demographic growth rate, migration flows and the survival probability vector vary over time. Taking account of migration enables us to use official demographic observations and projections.

2. Preferences

Individuals optimally choose their consumption and their investment in education when young (aged 15–25). Individuals have an uncertain lifetime duration, i.e. a probability of dying at the end of each period of life. In the spirit of Arrow–Debreu, we postulate the existence of a market for every contingent consumption. These markets open before the resolution of uncertainty: each individual has the possibility of insuring himself against uncertainty at the beginning of his life. Hence, the problem for agents born at time *t* is to select a consumption-contingent plan and the duration of his education in order to maximise his expected utility subject to his intertemporal budget constraint, given the sequence of contingent wages and prices.

The budget constraint requires equality between the expected value of expenditures and the value of income. Labour income is the sum of three components – return to raw labour (w^L), return to experience (w^E) and return

[4]It should be noted that our model is calibrated so as to match representative behaviour of French and American residents, including natives and foreign-born people. As illustrated in Borjas (2001) for the US, the 1965 Amendments to the Immigration and Nationality Act has drastically changed the national origin mix and the relative skills of immigrants, increasing their difference from natives. Obviously, a model with heterogeneous agents as in Storesletten (2000) would allow examination of the relative contribution of immigration to rising wage inequality and educational attainment.

to education (w^H). The expected value of income incorporates education decisions, public transfers and a mandatory retirement age.

3. Education and experience

Following Becker (1964), human capital is built essentially through on-the-job training and schooling; on-the-job training reflects the idea that 'many workers increase their productivity by learning new skills and perfecting old ones while on the job'. In the microeconometric literature on wage formation (Mincer-type equation), both education and experience are shown to have a strong influence on individual earning. Accordingly, we define human capital as having two major and substitutable components – education and experience. Education and experience have never been distinguished in existing general equilibrium models with realistic demographics, which at most endogenise labour participation rates by age. The hypothesis of perfect substitution between young workers and old workers is a common assumption in that literature. An exception is the paper by Heckman, Lochner and Taber (1998), who use a general equilibrium model with a sophisticated labour market. They calibrate their human capital production functions using econometric estimates of wage equations; however, they do not simulate their model with realistic population scenarios.

Labour supply is inversely related to the endogenous time invested in education when young. We also introduce an exogenous participation rate at later ages (this will be useful to capture the rise in women's labour market participation rates) and an exogenous time spent in retirement in the fifth period of life (i.e. between ages 55 and 65).

The education decision made in the first period of life is extremely important since it completely determines the vectors of experience, skills, education subsidies and public transfers for generation *t*. Following Wasmer (2001b), the individual stock of experience sums past labour market participation rates. The stock of education transforms education investment when young into labour efficiency according to a decreasing return function. Public transfers sum education subsidies, pension benefits and other transfers.

4. Technology

At each period of time, a representative firm uses labour in efficiency units Q_t and physical capital K_t to produce a composite good Y_t. The representative firm behaves competitively on the factor markets and maximises profits. We assume a Cobb–Douglas production function with constant returns to scale:

(1) $$Y_t = A_t K_t^{1-\varphi} Q_t^{\varphi}$$

where φ measures the share of wage income in the national product and A_t is an exogenous process representing total factor productivity.

The quantity of efficiency units of labour combines physical labour supply and human capital according to a Cobb–Douglas transformation function. Human capital is itself a combination of experience and education according to a CES (constant elasticity of substitution) nested transformation function. Formally, we have

$$(2) \qquad Q_t = L_t^{1-\delta}\left[\mu E_t^{\rho} + (1-\mu)\Theta_t H_t^{\rho}\right]^{\delta/\rho}, \quad \rho \leq 1$$

where L_t measures the input of manpower at time t, E_t measures the input of experience, H_t is the input of education, δ is a parameter representing the importance of human capital in the determination of labour income, and $1-\rho$ is the inverse of the elasticity of substitution between experience and education. Finally, Θ_t is exogenous skill-biased technical progress and μ is a parameter of preference for experience which is assumed to be time-invariant.[5]

We assume that workers belonging to different age groups are not perfect substitutes, because they have different education/experience mixes. However, the stocks of education and experience are homogeneous. The interest of this approach is that it is independent of the number of periods of life considered. If we had a model with generations living 55 periods, the production function (2) would remain unchanged. This is an advantage of our framework compared with Card and Lemieux (2001), who aggregate different age-group-specific human capital within a CES production function. In their approach, the number of embedded CES functions depends on how many groups there are.

5. The public sector

The government issues bonds and levies taxes on labour earnings (τ_t^w), consumption expenditures (τ_t^c) and capital income (τ_t^k) to finance public transfers and general public consumption. Five types of spending are distinguished – education subsidies, social security benefits, other transfers (healthcare, family allowance and social benefits), non-age-specific general consumption expenditure and interest payments on public debt. Several scenarios can be considered to balance this budget constraint. The budget can be balanced through tax adjustments, expenditure adjustments or

[5]Using a similar production function, Wasmer (2001a) shows that no residual trend is needed to match the observed path of returns to experience.

changes in the public debt. We assume in the following that the path of debt is given and that the tax rate τ_t^w adjusts to balance the budget.

6. Equilibrium

The equilibrium can be summarised as follows. Given a demographic structure, an initial generational distribution of education and wealth, and a policy (transfers, taxes and public debt path), a competitive equilibrium is a vector of prices and quantities such that (i) individuals maximise their utility subject to their lifetime budget constraint, (ii) firms maximise profits subject to technology, (iii) the rate of income tax balances the government budget and (iv) all markets clear.

In equilibrium, the optimal education investment balances the marginal gain of education (the future path of the net return to education) and the marginal cost of education; the marginal cost includes both the forgone wage when young and the forgone net return to experience.

The profit maximisation by firms requires the marginal productivity of each factor to equal its rate of return. The supply of experience and the supply of education influence the ratio of the rates of return for these two factors, w_t^E and w_t^H. We have

$$(3) \qquad \frac{w_t^H}{w_t^E} = \frac{1-\mu}{\mu}\left[\frac{H_t}{E_t}\right]^{\rho-1} \Theta_t .$$

If ρ is less than one, an increase in the stock of experience stimulates the rate of return to education. Any technical change Θ_t will also affect the ratio.

III. Calibration

Two model economies are calibrated – one for France and one for the US – in order to reproduce some characteristics of these countries. Calibration involves using data for the observed exogenous variables, fixing some constant parameters and choosing paths for the unobserved exogenous variables in order to match a series of characteristics. Calibration is not focused on reproducing the characteristics of a given steady state, where all the interesting information on population history, experience stocks and skills by age group would be lost. Instead, the equilibrium is computed as a transition from one steady state in 1900 to another in 2250. By starting in 1900, the stocks of education and experience around 1960 reflect the correct history of the population.

1. Observed exogenous variables

Demography. Past and future population shares by age are taken from official demographic institutes. For France, we use observations and forecasts from INED and INSEE. For the US, data and forecasts are taken from the Population Division of the US Census Bureau. As for demographic projections, we use the central scenario for both countries. The population aged 95 and over is not taken into account in either country.
Education and participation rates. Appendix B presents the data on education and participation rates. The time invested in education is computed using school attendance measures and educational attainment. The old-age participation rate is computed using the effective retirement age data. Overall participation rates are normalised to 1 in 2000 and computed from Wasmer (2001a).
Public finance. In our model, we have three proportional taxes – the labour income tax, the capital income tax and indirect taxes. We also distinguish two types of government spending (net of debt charges) – non-age-specific public consumption and age-specific transfers taken from generational accounting studies. Social security benefits and other individual transfers evolve exogenously. The path of public debt is given exogenously and the labour income tax adjusts to balance the budget. Appendix C describes the data sources for these variables.

2. Parameters

A set of parameters is set a priori, the same for both countries. By doing so, we minimise the amount of assumed differences between France and the US. The labour share in output, φ, is set to 0.7. This value is commonly used in calibrated models of the US economy. In France, the labour share was 0.693 in 1995, according to INSEE. The depreciation rate of capital is set to 0.4. This value implies an annual depreciation rate of 5 per cent. The depreciation rate of experience will follow the median hypothesis of Wasmer (2001b), i.e. an annual rate of 3 per cent, independent of age. The depreciation rate per decade, θ_e, is equal to 0.737. The parameter μ in the production function is a scale parameter of no importance given the later choice of Θ_t; it is set to 0.5. Two parameters are important in shaping the wage profile over age: the share of raw labour in labour income ($1–\delta$) is set to 0.4 and the scale parameter in the production function of human capital (ε) is set to 1.2. Together, these values deliver an adequate wage profile (see below).

The two elasticity parameters are of special importance. The parameter ρ determines substitution between education and experience. It is set to –0.9 according to Wasmer's (2001a) estimates, implying a low substitutability

($1/(1-\rho) = 0.52$) between the two components of human capital. The parameter ψ is the elasticity of education capital to investment in education. It should be calibrated using the estimated elasticity of future earnings with respect to additional schooling (see, for example, Psacharopoulos (1994) for a survey of these elasticities); we take the value $\psi = 0.6$, which is in accordance with a return to an additional year of schooling of 11.5 per cent, assuming that this additional year of schooling raises education expenditure by 20 per cent.

3. Identification of unobserved exogenous variables

Explaining the skill premium and educational investment requires identification of exogenous variables for which time-series data are not available. Our methodology follows two steps. We first define a baseline scenario where we use the model to identify the unobserved exogenous variables. In this step, the skill premium and educational investment will be matched exactly by the model. In the second step, we compute the hypothetical path of the skill premium and educational investment by keeping constant different exogenous variables; by doing so, we evaluate the relative contribution of each exogenous process to the endogenous outcomes.

There are five unobserved exogenous variables – total factor productivity A_t, the rate of subsidy on education expenditures v_t, the skill-biased technical progress Θ_t, the level of pension benefit b_t and the scale of the age-specific transfer profile g_t. These five exogenous processes are chosen so as to match available time-series data for five endogenous variables which are closely related to the unknowns: the GDP growth rate, the shares of social security and of other transfers in GDP, the education investment of young cohorts and the return to education. The return to education is based on the data provided in Section I. For the skill premium prior to 1960, we consider it constant at its 1960 value.[6]

Basically, our identification process involves swapping five exogenous variables for five endogenous variables and solving the identification step with the algorithm proposed by Laffargue (1990) and Boucekkine (1995).[7] The identification of education policy captures changes in the characteristics of the education system. The skill-biased technical progress captures changes in the productivity of skills, affecting the demand side of the labour market. Technical change is allowed to differ across countries.

[6]An alternative is to use Goldin and Katz (1999), who provide data since 1920; unfortunately, such estimates are not available for France.

[7]Our identification process resembles Sims's (1990) backsolving method for stochastic general equilibrium models. We use a similar idea of treating exogenous processes as endogenous, not to solve a model but as a calibration device in a deterministic framework.

Our backsolving identification procedure allows us to calibrate the model 'dynamically'. This is much better and more rigorous than calibrating on a hypothetical steady state (in 1900 or in 2250) and rescaling exogenous variables to obtain reasonable outcomes at a given date, as is usually done in the tradition of Auerbach and Kotlikoff (1987).

To match labour market trends over the period 1960–2000, we need to specify agents' expectations about the future. Expectations over the period 2010–80 are indeed important in determining optimal behaviour over the period 1960–2000. We now describe our main assumptions:

- The shares of public pensions and other transfers in GDP are kept constant (this usually requires individual benefits to grow at a slower pace than labour productivity). This assumption is in line with the US projections of the Congressional Budgetary Office.
- The public debt to GDP ratio is constant after 2000.
- Between 2000 and 2030, retirement age will gradually increase from 58.7 to 60 in France, reflecting current policy changes. In the US, retirement age is kept constant at 62.5.
- The US educational attainment (among the population aged 25 and over) matches US official projections, which are reported in Cheeseman Day and Bauman (2000). They are based on separate educational attainment rates by race, ethnic group, gender, age and place of birth. We opt for the 'high' projection scenario in which the proportion of the population aged 30 to 35 and graduating from high school and higher grows from 89.6 per cent in 2003 to 94.8 per cent in 2028 (from 59.2 per cent to 70.2 per cent for College and from 28.7 per cent to 32.2 per cent for Bachelors). Combining these numbers to obtain the average time devoted to education between ages 15 and 24, it appears that the time invested in schooling increases from 59.1 per cent in 1990 to 67.0 per cent in 2030. We consider that the educational attainment of future young cohorts in France will converge toward the US level between 1990 and 2030; this implies that the time invested in education will grow from 51.0 per cent in 1990 to 67.0 per cent in 2030.
- In both countries, the growth rate of GDP converges linearly within two decades toward a long-run level of 20 per cent per decade. This assumption ensures that the income gap between the two countries does not grow unboundedly over time.
- In both countries, the skill premium is kept at its last observed value; as this conjecture is not based on any available information, Section V will provide a sensitivity analysis to this assumption.

4. Identified shocks

Before doing the counterfactual experiments, let us briefly examine the results of our identification process. Figure 3 depicts the implicit education subsidies v_t between 1950 and 2050 and the identified skill-biased technical progress Θ_t.

Education policies are very different. Between 1960 and 1980, the educational policy in France was highly expansionary, while in the US it became strongly discouraging in the early 1970s and the 1980s. There are several stylised facts explaining this difference. In France, the student strikes of May 1968 initiated a deep debate on the role of educational policies. In the 1980s, the government announced its objective of an 80 per cent pass rate for the *baccalauréat*. Various specific policies have been intended to decrease the cost of education. In the US, OECD indicators show that the share of public spending in total education expenditure has fallen over time. It decreased from 88 per cent in 1988 to 75 per cent in 1995 (for higher-education programmes only, it stood at 47 per cent in 1995). It should be noted that France's corresponding percentages were 88 per cent in 1988 (the same as in the US) and 92 per cent in 1995. Since 2000, education policies have become quite stable, and they are expected to remain so.

This difference in education policies can be corroborated by considering the ratio of the price index of education goods (tuition fees, other school fees, etc.) to the overall price index. Figure 4 plots these 'relative prices' of education for both countries. For the US (right panel), the ratio of the two price indices shows that the cost of education in terms of the aggregate consumption good more than doubled between 1978 and 2002, reflecting sharp increases in tuition fees. For France, there is no decline, but the rise in the cost of education is much smaller.

FIGURE 3

Identified implicit education subsidy v_t and skill-biased technical change Θ_t

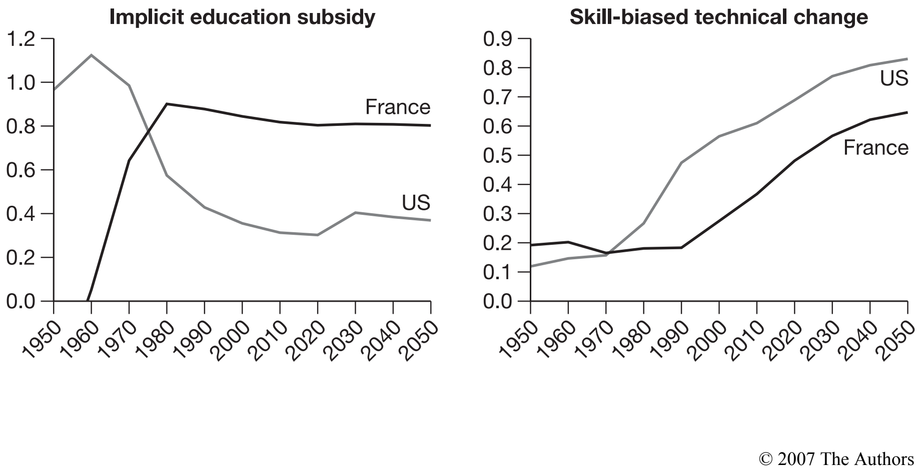
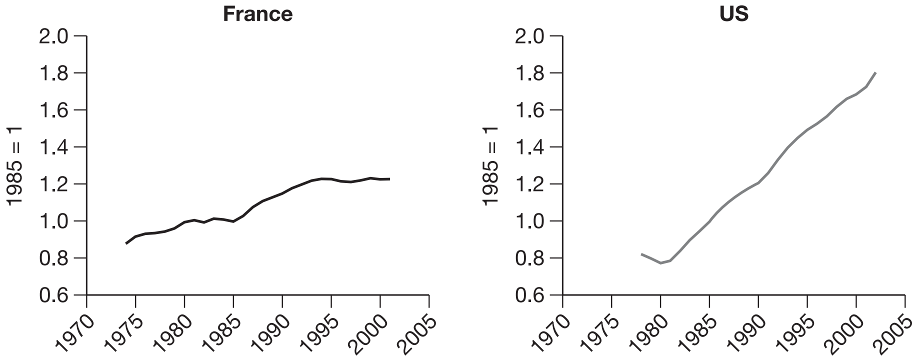


FIGURE 4

Relative price of education



Looking more deeply into the US cost structure of education (from the Department of Education), we observe that nominal tuition and required fees have increased by a factor of 6.10 from 1976 to 2000 in private institutions and by a factor of 5.42 in public institutions. The cost of dormitory rooms has increased by a factor of 5.19 in private schools and 4.41 in public schools. The cost of boarding has increased by a factor of 3.78 in private schools and 3.37 in public schools. Over the same period, the overall price index increased by a factor of 2.72.

Going back to Figure 3, we observe that, between 1970 and 2000, skill-biased technical change was strong in the US but not in France. In the literature, skill-biased technical change has been related to investment in information technology and/or to patterns in international trade. As far as information technologies are concerned, data presented in Dunaway, Kaufman and Luzio (2001) display a pattern similar to our measured technical progress: the percentage of GDP allocated to investment in information technology rose in the US from 7.5 per cent to 9 per cent between 1992 and 1999, while it stayed constant in France at around 6 per cent. Moreover, Card, Kramarz and Lemieux (1999) report that the proportion of workers using a computer is somewhat higher in the US than in France (37.4 per cent in the US in 1989 and 34 per cent in France in 1991). Machin and Van Reenen (1998) relate skill-biased technical change to R&D intensity. Their data show that the share of R&D in GDP increased both in France and in the US, but stays 3 percentage points higher in the US over the period 1973–89. Concerning international trade, Card, Kramarz and Lemieux (1999) show that the US also experienced a larger increase in the imports/GDP ratio from less developed countries between 1973 and 1993 (the higher are the imports from LDCs, the more likely the country is to be specialised in high-skill activities).

After 2000, our model exhibits a convergence process between the countries even if, in the long run, the skill bias remains stronger in the US.[8] This result is consistent with the vast literature on the technical leadership of the US economy. Since 1870, European growth performances have been driven by delayed technological innovation simply accomplished by mimicking US achievement. According to Gordon (2002), the current dominance of the US in information and communications technology (ICT) can be related to issues such as patent protection, securities regulation, the role of venture capital and the large funding policy of hi-tech companies.

Following our identification procedure, it takes between 20 and 30 years for France to adopt US knowledge. This is somewhat lower than the delay observed for major past innovations. The transformation of Western Europe achieved by electricity and internal combustion began in the 1950s, almost 40 years after that in the US. Similarly, the percentage of French households owning a car mimicked the equivalent US ratio roughly 40 years later.

How can we explain such a delay of 20–30 years? A host of studies have found evidence that the recent skill-biased technical progress leads to organisational changes within firms (employees perform a wider range of tasks and have more responsibility). Caroli and Van Reenen (2001) provide evidence that organisational changes leading to increases in productivity can only be observed in workplaces with high levels of skills. On this basis, they find some support for a stronger skill-biased technical change in Britain than in France. Similarly, the US leadership appearing on Figure 3 can be seen as resulting from a higher level of education of the US labour force in the 1970s and 1980s. As shown on Figure B1 in Appendix B, the educational attainment of young French cohorts in 1990 equals that of US young cohorts in 1970.

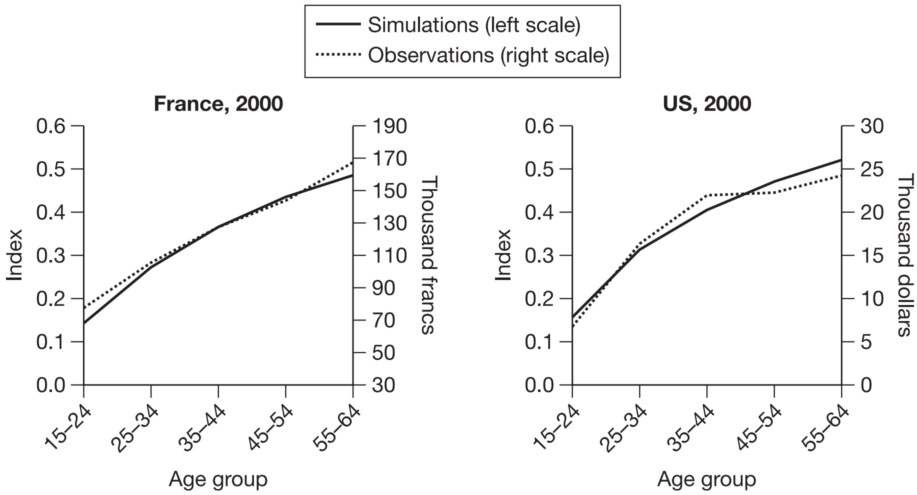
5. Wage and asset profiles over age

The quality of our model depends on its ability to match individual profiles over age. Let us focus on wage and wealth profiles. Figure 5 provides the wage profile over age for the year 2000, comparing for each country the model's outcome with actual data (INSEE for France and PSID for the US). The concave shape of the profile over age is fully determined by the accumulation and depreciation of experience; there is no need to assume an exogenous profile as in Auerbach and Kotlikoff (1987). This graph comforts us in our choice of technological parameters and depreciation rates.

[8]For a model explaining why technological leadership may persist even at steady state, see Cozzi (2002).

FIGURE 5

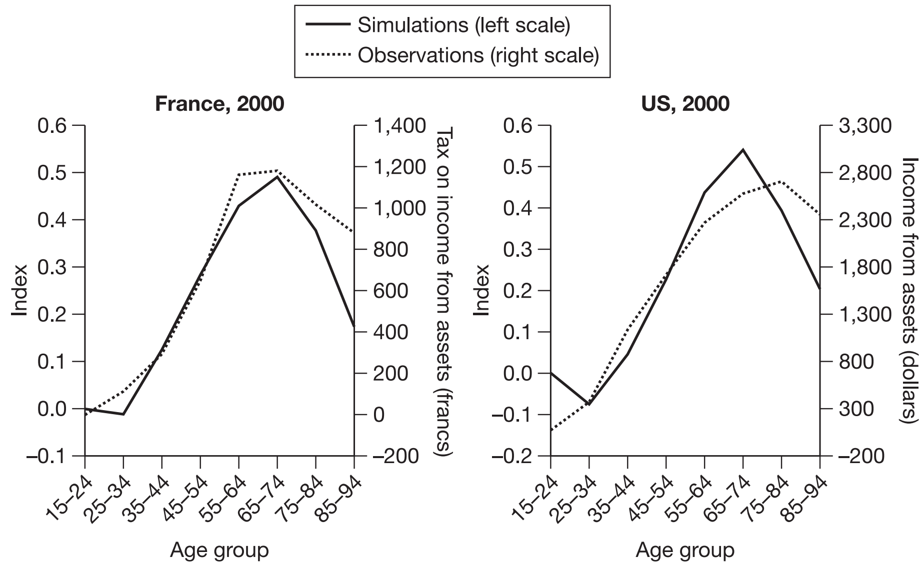
Wage profile over age



Note: Wages are measured in domestic currencies, current prices.
Source: INSEE (see Crettez, Feist and Raffelüschen (1999)) for France. Authors' computations from PSID (total labour income before tax) for the US.

FIGURE 6

Asset profile over age



Note: Assets are measured in domestic currencies, current prices.
Source: INSEE (see Crettez, Feist and Raffelüschen (1999)) for France. Authors' computations from PSID (total asset income, assuming that asset stocks are proportional to asset income) for the US.

It is usually argued that the standard life-cycle model with selfish households does not provide a good description of wealth accumulation after retirement. Figure 6 reports our simulated asset profiles over age in the year 2000, together with their empirical counterparts (INSEE for France and PSID for the US). It appears that our model matches the profiles, except for very old people (aged 85–94). Hence, there is no need to suppose a pure time preference parameter on top of the mortality rate. The annuity market is also helpful in avoiding poverty in old age.

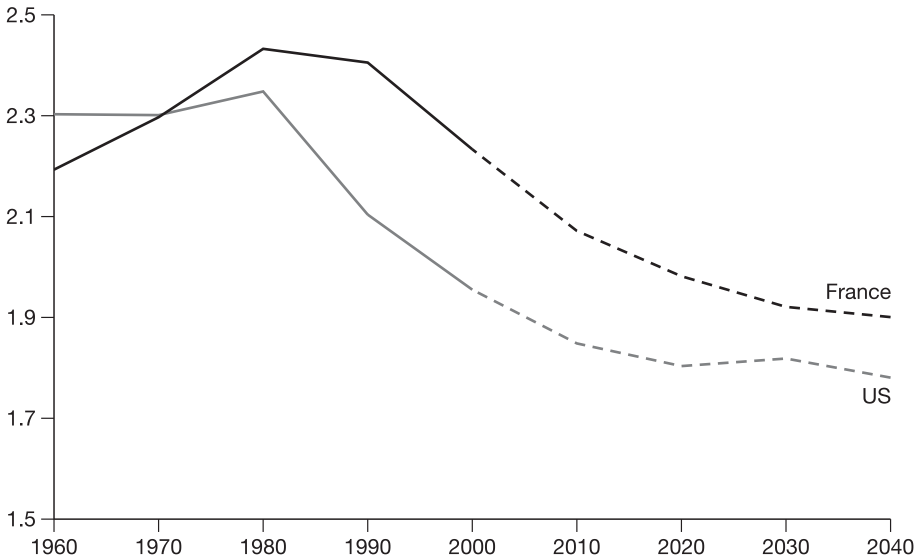
6. The return to experience

The return to experience is an endogenous outcome of the model. Figure 7 gives the simulated return to 20 years of experience for France and the US. This return is a decreasing function of E_t/L_t and Θ_t.[9]

Changes in the population structure by age and in technology are the driving forces affecting the experience premium. Between 1960 and 1980, the average experience of workers (as measured by E_t/L_t) fell in both countries. As a result, the return to experience increased over that period, as is reflected in Figure 7. Our simulations correctly depict the fact that the experience premium increased more in France than in the US between 1960 and 1980. This difference between the two countries is mainly due to the

FIGURE 7

Simulated return to experience (20 years)



[9]This can be easily shown by combining equations (A26) and (A27) in Appendix A.

stronger skill-biased technical change in the US. Indeed, the average experience of workers decreases more in the US than in France. Without technical progress (as measured by Θ_t), the rise in the experience premium would have been stronger in the US. However, the US skill-biased technical change did offset an important part of the rise in the experience premium.

Between 1980 and 2020, ageing induces a sharp increase in the average experience of workers. This explains why the return to experience starts decreasing after 1980, an evolution that is compatible with Wasmer's numbers presented in Figure 2. For the next decades, our simulations provide a similar time path for both countries. The rise in the stock of experience is lower in France (+20 per cent) than in the US (+30 per cent) but the French skill-biased technical change produces its effects after 2000 and reinforces the impact on the experience premium.

IV. Explaining the skill premium and education paths

Our analysis will now rely on counterfactual experiments. We compute six hypothetical paths of skill premiums and educational attainment, each path being obtained by keeping one exogenous variable at its 1960 level. The six exogenous variables we consider are demographics (including mortality, fertility and migration), skill-biased technical progress, the overall participation rate, the effective retirement age, welfare programmes and education subsidies. Such experiments allow us to evaluate the marginal impact of each exogenous variable on endogenous variables. Table 1 presents the difference between the benchmark simulation and the counterfactual, which isolates the contribution of each exogenous variable to the rise in educational attainment for France and the US. Notice that each number represents a cumulated impact on the time devoted to education between ages 15 and 24, u_t.

TABLE 1

Explaining the changes in school attendance (percentage deviation from baseline)

	France				US			
	1970	*1980*	*1990*	*2000*	*1970*	*1980*	*1990*	*2000*
Demographics	–0.02	–0.01	+0.05	+0.07	–0.04	+0.01	+0.09	+0.05
Technical bias	+0.00	+0.04	+0.18	+0.26	+0.25	+0.30	+0.32	+0.35
Participation	+0.02	+0.06	+0.09	+0.11	+0.04	+0.07	+0.09	+0.09
Welfare state	–0.02	–0.03	–0.02	–0.01	–0.01	–0.02	–0.01	+0.00
Early retirement	–0.04	–0.08	–0.09	–0.10	–0.03	–0.02	–0.02	–0.03
Education policy	+0.05	+0.10	+0.12	+0.12	+0.06	–0.11	–0.16	–0.15

Note: The table shows the difference between the simulated baseline values and the counterfactual experimental values when each exogenous variable is kept constant in turn.

TABLE 2

Explaining the changes in the skill premium (percentage deviation from baseline)

	France				US			
	1970	*1980*	*1990*	*2000*	*1970*	*1980*	*1990*	*2000*
Demographics	–0.01	–0.02	–0.06	–0.06	+0.10	+0.04	–0.05	–0.06
Technical bias	–0.06	–0.02	–0.14	–0.05	–0.15	–0.03	+0.13	+0.08
Participation	–0.02	–0.05	–0.08	–0.11	–0.02	–0.05	–0.07	–0.07
Welfare state	+0.01	+0.03	+0.06	+0.06	+0.02	+0.02	+0.03	+0.02
Early retirement	+0.05	+0.08	+0.10	+0.08	+0.03	+0.03	+0.03	+0.03
Education policy	+0.03	–0.06	–0.23	–0.34	–0.06	–0.05	+0.06	+0.14

Note: The table shows the difference between the simulated baseline values and the counterfactual experimental values when each exogenous variable is kept constant in turn.

School attendance is higher in the benchmark than in the simulation where demographic variables are kept constant; this highlights the well-known result that educational attainment increases with life expectancy, which is an important component of demographic changes. Skill-biased technical progress has encouraged education in both countries by increasing firms' demand for skilled workers. Women's increasing labour market participation explains an important part of education decisions. Indeed, higher participation when adult increases the individual return to educational investment. In both countries, the impact of changes in welfare state policy (taxes and transfers) is quite low. This is also true for the decrease in effective retirement age, especially in the US. The major difference between France and the US concerns the role of education policies: between 1960 and 1970, French education policy became expansionary. The positive impact on education investment was especially strong in the 1980s and beyond in France; in the US, the discouraging education policy became important in the late 1970s and the 1980s and remained so for the rest of the century.

Table 2 provides the contribution of each exogenous variable to the skill premium in France and the US. The skill premium measures the wage increase enjoyed by an individual investing 30 per cent of his time in education compared with an individual with no education investment between ages 15 and 24 ($w^H(\varepsilon 0.3^{\psi})/w^L$).

Since the 1980s, demographic shocks have exerted a negative impact on the skill premium in both countries. However, before 1985, the effect of demographics was positive in the US: the impact of the demographic structure on the stock of experience was more important than the stimulating effect on the stock of education. Early retirement has had a positive impact on the skill premium, as have welfare state programmes. Two opposite results emerge. First, education policies have had diverging effects: in

TABLE 3

Explaining the changes in the experience premium (percentage deviation from baseline)

	France				US			
	1970	*1980*	*1990*	*2000*	*1970*	*1980*	*1990*	*2000*
Demographics	+0.08	+0.10	+0.06	+0.00	+0.18	+0.65	+0.34	+0.01
Technical bias	+0.03	+0.00	–0.02	–0.06	–0.51	–0.81	–1.01	–1.01
Participation	+0.00	–0.03	–0.10	–0.15	–0.09	–0.30	–0.52	–0.71
Welfare state	+0.00	+0.00	–0.01	–0.02	+0.00	+0.00	–0.05	–0.05
Early retirement	+0.03	+0.07	+0.09	+0.08	+0.04	+0.19	+0.14	+0.11
Education policy	–0.03	–0.02	+0.02	+0.07	–0.05	+0.56	+0.11	+0.17

Note: The table shows the difference between the simulated baseline values and the counterfactual experimental values when each exogenous variable is kept constant in turn.

France, the expansionary policy stimulated the stock of skills and exerted a negative impact on the skill premium; in the US, the skill premium has been boosted by restrictive policies for the last thirty years. Second, the impact of technical shocks has been different. In France, the skill-biased technical shock has had a slightly negative impact on the skill premium: this is because the effective skill-biased technical change has been very low between 1960 and 1990 but is expected to be strong in the next decades; such expectations have increased the supply of skills but not yet the demand; hence, the current skill premium is depressed. In the US, the impact of skill-biased technical change is strongly positive; this is the usual effect put forward by, among others, Machin and Van Reenen (1998): technical change has had a clear effect of increasing the relative demand for skilled workers.

Table 3 provides the contribution of each exogenous variable to the experience premium for France and the US. Almost all the exogenous processes have had similar qualitative effects on the returns to experience in France and in the US. However, the magnitude of the effects has been greater in the US. In particular, the US technical bias and increasing participation rates have had major negative impacts on the experience premium.

V. Sensitivity analysis

In this section, we study the sensitivity of the identification procedure to two key assumptions.

First, we investigate the quantitative importance of having assumed that the skill premium is constant after the year 2000. For that purpose, we consider two alternative scenarios about the evolution of the skill premium between 2000 and 2050. The first considers an increasing skill premium (15 per cent higher than the baseline from 2010 onwards). The second scenario considers a decreasing skill premium (15 per cent lower from 2010 onwards).

Figure 8 presents the sensitivity of the skill-biased technical change and of the education subsidy rate. It shows that the identified skill bias is highly robust between 1950 and 2000, only being affected by skill premium expectations after 2000. The identified education subsidy rate is more sensitive from the 1980s onwards, and especially after 1990. Considering an increasing (a decreasing) skill premium requires a lower (a higher) education subsidy rate to match observed educational attainment. Our conclusion about the changes in education policy still holds. Between 1960 and 2000, French education policy was expansionary. In contrast, US policy was less generous over the period 1980–2000 than in 1960. As a consequence, the general picture presented in Tables 1 and 2 remains valid, but the magnitude of the impact of education policies and technical changes on human capital

FIGURE 8

Sensitivity of technical bias and of education subsidy to expected skill premium

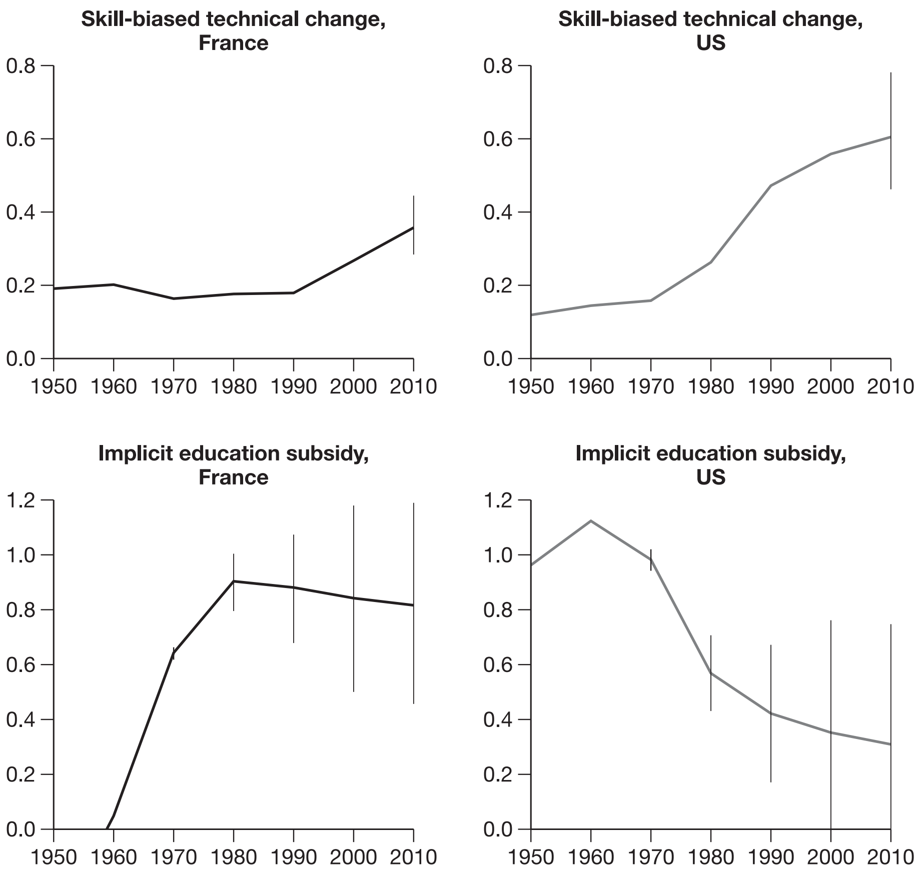
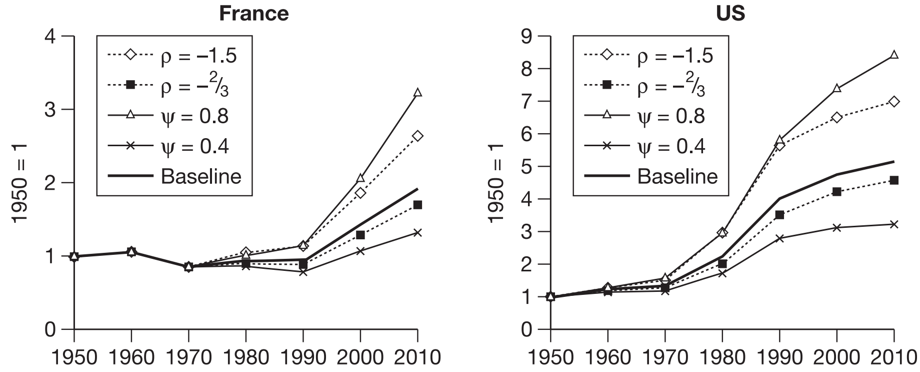


FIGURE 9

Sensitivity of technical bias to elasticities



investments and on the return to skill is likely to be sensitive to skill premium expectations for 1990 and 2000.

Second, we examine sensitivity to the main elasticities. We consider two alternative values for the elasticity of education-related human capital to schooling ($\psi = 0.8$ and $\psi = 0.4$) and two alternative values for the elasticity of substitution between education and experience in the production function ($\rho = -1.5$ and $\rho = -2/3$, inducing elasticities equal to 0.4 and 0.6 respectively). Figure 9 depicts the sensitivity of skill-biased technical change to the elasticities.[10]

For a given schooling investment, the stock of education-related human capital increases with ψ. Hence, compared with the baseline (the bold line in Figure 9), a larger ψ induces a stronger downward pressure on the skill premium. More skill-biased technical change is required to match the skill premium time path. This is why we observe that the estimated technical bias is stronger with $\psi = 0.8$ than in the baseline. Similarly, the price responses to changing stocks increase with the elasticity of substitution between experience and education, $1/(1-\rho)$. When the elasticity decreases, the rise in the stock of education (relative to the stock of experience) creates a stronger downward pressure on the skill premium. More skill bias is needed to match the return to schooling. This sensitivity analysis highlights the importance of distinguishing between experience and education as two distinct components of human capital. The elasticity of substitution between the two determines the size of skill bias required to match observations. Hence, modelling experience affects the marginal contribution of technical changes to skill premiums and wage inequality.

[10]Ideally, changing the elasticities would require modification of other parameters (such as the scale parameter in the human capital technology) to let the model match observations. Here we only look at skill-biased technical change since the scale of this variable does not matter.

VI. Conclusion

In this paper, we develop an original model to explain how disparities in public policies (education subsidies, welfare programmes, retirement age and taxation) and in the economic and demographic environments explain diverging patterns of education and wage inequality in France and the US. Education and experience are seen as two components of human capital. By endogenising education choices, our model accounts for important interactions between human capital investment and (actual and expected) returns to skills. It also allows us to evaluate the relative impacts of exogenous factors such as public policies, demographic variables, female labour market participation and technical progress.

Our calibration technique allows us to identify technical and policy shocks affecting the US and French economies in the post-war period. Between 1970 and 2000, we show that skill-biased technical change was strong in the US and affected France with a delay. Such differences in skill biases are important in understanding the diverging patterns of returns to skills. The skill-biased technical shock had a low impact in France and a strong impact in the US. In that respect, in the US case, our model comforts the demand-side view of Katz and Murphy (1992), Juhn, Murphy and Pierce (1993), Bound and Johnson (1992) and others.

However, supply-side changes in educational attainment were crucial to explaining the decrease in returns to skills in France. French education policy had a positive impact on education investment especially in the 1980s and beyond; in the US, the discouraging education policy became important in the late 1970s and the 1980s and remained so for the rest of the century. We provide several stylised facts explaining these differences. Consequently, education policies exerted a negative impact on the skill premium in France and a positive but moderate impact in the US.

Appendix A. Detailed description of the model

A1. Demographics

The size of the youngest generation increases over time at an exogenous growth rate:

$$\text{(A1)} \qquad N_{0,t+1} = N_{0,t} m_t$$

where $N_{0,t}$ measures the initial size of generation t and m_t is one plus the demographic growth rate, including both fertility and migration.

The size of each generation is given by

$$\text{(A2)} \qquad N_{a,t+a} = N_{0,t} \beta_{a,t+a} + M_{a,t+a}$$

where $0 \leq \beta_{a,t+a} \leq 1$ is the fraction of generation t alive at age a (hence, at period $t+a$) and $M_{a,t+a}$ is the stock of migrants of age a. We also have $\beta_{0,t} = 1$. Obviously, the total population at time t amounts to $N_t = \sum_{a=0}^{7} N_{a,t}$.

A2. Preferences

The expected utility function is assumed to be time-separable and logarithmic:

$$\text{(A3)} \qquad E(U_t) = \sum_{a=0}^{7} \beta_{a,t+a} \ln\left(c_{a,t+a}\right)$$

where $c_{a,t+a}$ is the consumption of generation t at age a.

For a standard individual born at age 0 at time t, the budget constraint is

$$\text{(A4)} \qquad \sum_{a=0}^{7} p_{a,t+a}\left[c_{a,t+a}\left(1+\tau_{t+a}^{c}\right) - T_{a,t+a}\right] = \sum_{a=0}^{7}\left(\eta_{a,t+a}^{L} + \eta_{a,t+a}^{E} e_{a,t+a} + \eta_{a,t+a}^{H} h_{a,t+a}\right) l_{a,t+a}$$

where τ_{t+a}^{c} is the consumption tax rate at period $t+a$, $p_{a,t+a}$ is the price of one unit of good in the case of the individual being alive at age a, and $T_{a,t+a}$ denotes the amount of transfer received at age a including education benefits, pensions and other transfers (healthcare, family allowances, social benefits, etc.). $e_{a,t+a}$ and $h_{a,t+a}$ measure the stock of experience and education at age a, while $l_{a,t+a}$ measures labour supply at age a; raw labour, experience and education are supplied at net-of-taxes contingent wages $\eta_{a,t+a}^{L}$, $\eta_{a,t+a}^{E}$ and $\eta_{a,t+a}^{H}$.

We can also define the implicit asset holdings $s_{a,t+a}$ of each cohort as follows:

$$\text{(A5)} \qquad p_{0,t}s_{0,t} = \left(\eta_{0,t}^{L} + \eta_{0,t}^{E} e_{0,t} + \eta_{0,t}^{H} h_{0,t}\right) l_{0,t} - p_{0,t}\left[c_{0,t}\left(1+\tau_{t}^{c}\right) - T_{0,t}\right]$$

$$\text{(A6)} \qquad p_{a,t+a}s_{a,t+a} = p_{a-1,t+a-1}s_{a-1,t+a-1} + \left(\eta_{a,t+a}^{L} + \eta_{a,t+a}^{E} e_{a,t+a} + \eta_{a,t+a}^{H} h_{a,t+a}\right) l_{a,t+a} - p_{a,t+a}\left[c_{a,t+a}\left(1+\tau_{t+a}^{c}\right) - T_{a,t+a}\right].$$

For an individual already living at the initial date (i.e. with age $j = 1,\ldots,6$ at date 0), the budget constraint is

(A7) $$\sum_{a=j}^{7} p_{a,t+a}\left[c_{a,t+a}\left(1+\tau_{t+a}^{c}\right)-T_{a,t+a}\right] = p_{j-1,-1}s_{j-1,-1}+\sum_{a=j}^{7}\left(\eta_{a,t+a}^{L}+\eta_{a,t+a}^{E}e_{a,t+a}+\eta_{a,t+a}^{H}h_{a,t+a}\right)l_{a,t+a}\,.$$

The variable $s_{j-1,-1}$ represents the initial asset holdings of this individual. This budget constraint is also the one of a migrant entering the country at age j. For simplicity, we assume that migrants of each generation have the same characteristics as a native individual of that generation and have the same implicit wealth, experience and education.

A3. Education and experience

The vector of labour supply for generation t (defining labour supply at all ages) is

(A8) $$\overline{l}_t=\left(q_t\left(1-u_t\right),q_{t+1},q_{t+2},q_{t+3},q_{t+4}\left(1-\alpha_{t+4}\right),0,0,0\right)$$

where q_t is the exogenous participation rate at time t, $0 \le u_t \le 1$ measures the endogenous time invested in education in the first period of life and α_{t+4} stands for the (exogenous) time spent in retirement in the fifth period of life.

The vector of the individual stock of experience is

(A9) $$\overline{e}_t=(0,\left(1-u_t\right)\theta_e^1q_t,\left(1-u_t\right)\theta_e^2q_t+\theta_e^1q_{t+1},\left(1-u_t\right)\theta_e^3q_t+\theta_e^2q_{t+1}+\theta_e^1q_{t+2}, \left(1-u_t\right)\theta_e^4q_t+\theta_e^3q_{t+1}+\theta_e^2q_{t+2}+\theta_e^1q_{t+3},0,0,0)$$

where $\theta_e^a\in(0,1)$ represents one minus the depreciation of experience over the lifetime.

The vector of the individual stock of education is

(A10) $$\overline{h}_t=\left(0,\varepsilon u_t^{\psi},\varepsilon u_t^{\psi},\varepsilon u_t^{\psi},\varepsilon u_t^{\psi},0,0,0\right)$$

where $\varepsilon > 0$ and $\psi\in(0,1)$ are two parameters of the educational technology.

The vector of public transfers is:

(A11) $$\overline{T}_t=(v_tq_tu_t\eta_{0,t}^{L}+\gamma_0g_t,\gamma_1g_{t+1},\gamma_2g_{t+2},\gamma_3g_{t+3},\alpha_{t+4}b_{t+4}+\gamma_4g_{t+4}, b_{t+5}+\gamma_5g_{t+5},b_{t+6}+\gamma_6g_{t+6},b_{t+7}+\gamma_7g_{t+7})$$

where v_t is the rate of subsidy on the cost of education, b_t is the pension benefit allocated to each full-time retiree at period t and $\gamma_a g_t$ is the amount of age-related transfer made by the government to agents of age a.[11] The parameter γ_a describes the share of total transfer g_t in favour of age a.

A4. Technology

At each period of time, a representative firm uses labour in efficiency units Q_t and physical capital K_t to produce a composite good Y_t. We assume a Cobb–Douglas production function with constant returns to scale:

$$\text{(A12)} \quad Y_t = A_t K_t^{1-\varphi} Q_t^{\varphi}$$

where φ measures the share of wage income in the national product and A_t is an exogenous process representing total factor productivity. Human capital is itself a combination of experience and education according to a CES nested transformation function:

$$\text{(A13)} \quad Q_t = L_t^{1-\delta}\left[\mu E_t^{\rho} + (1-\mu)\Theta_t H_t^{\rho}\right]^{\delta/\rho}, \quad \rho \le 1$$

where L_t measures the input of manpower at time t, E_t measures the input of experience, H_t is the input of education, δ is a parameter representing the importance of human capital in the determination of labour income, $1-\rho$ is the inverse of the elasticity of substitution between experience and education, and μ is a parameter of preference for experience. Finally, Θ_t is exogenous skill-biased technical progress.

The representative firm maximises profits:

$$\text{(A14)} \quad Y_t - (r_t + d)K_t - w_t^L L_t - w_t^H H_t - w_t^E E_t$$

where r is the interest rate, d is the depreciation rate of physical capital, w^L is the return to raw labour, w^H is the return to education and w^E is the return to experience.

A5. The public sector

The government budget constraint may be written as

$$\text{(A15)} \quad \tau_t^w\left(w_t^L L_t + w_t^E E_t + w_t^H H_t\right) + \tau_t^c C_t + \tau_t^k r_t K_t + D_{t+1} - (1-r_t)D_t$$
$$= N_{0,t} v_t q_t u_t w_t^L\left(1-\tau_t^w\right) + \sum_{a=0}^{7} N_{a,t}\gamma_a g_t + \vartheta_t Y_t + \left(N_{4,t}\alpha_t + \sum_{a=5}^{7} N_{a,t}\right) b_t$$

[11]This variable only captures transfers that can be used for private consumption.

where C_t is aggregate private consumption, D_t denotes the public debt at the beginning of period *t*, ϑ_t is the share of non-transfer public consumption in GDP and $\gamma_a g_t$ is the amount of transfer per capita allocated to individuals of age *a*. Taxes bear on labour earnings (τ_t^w), consumption expenditures (τ_t^c) and capital income (τ_t^k).

A6. Equilibrium

At each date, the composite good is taken as numeraire. The spot price is thus normalised to one: $p_t = 1$. If we denote by r_{t+1} the interest rate between dates *t* and *t*+1, the appropriate discount factor applied to age-*a* income and spending is given by

$$\text{(A16)} \quad R_{a,t+a} \equiv \prod_{s=t+1}^{t+a} \left(1 + r_s \left(1 - \tau_s^k\right)\right)^{-1}$$

where, by convention, $R_{0,t} = 1$. Spot gross wages at time *t*+*a* are denoted by w_{t+a}^L, w_{t+a}^H and w_{t+a}^E. They correspond to the marginal productivities of labour components, as shown below.

Since there is perfect competition on the insurance market, the contingent prices are related to the spot prices through a set of no-arbitrage conditions. The equilibrium (discounted) contingent prices of the consumption good at time *t* are given by

$$\text{(A17)} \quad p_{a,t+a} = R_{a,t+a} \beta_{a,t+a} .$$

Equilibrium (discounted) contingent net wages are

$$\text{(A18)} \quad \begin{aligned} \eta_{a,t+a}^L &= R_{a,t+a} \beta_{a,t+a} w_{t+a}^L \left(1 - \tau_{t+a}^w\right) \\ \eta_{a,t+a}^E &= R_{a,t+a} \beta_{a,t+a} w_{t+a}^E \left(1 - \tau_{t+a}^w\right) \\ \eta_{a,t+a}^H &= R_{a,t+a} \beta_{a,t+a} w_{t+a}^H \left(1 - \tau_{t+a}^w\right) \end{aligned}$$

where τ_{t+a}^w denotes the rate of tax on labour income at time *t*. The originality of the model is that labour income consists of three components – manpower, experience and education. Equivalently, individual gross wages are the sum of these three elements, so that a tax on labour income, τ_t^w, affects all wage components similarly.

The equilibrium condition on the goods market may be written as follows:

$$\text{(A19)} \quad Y_t + K_t^* = \underbrace{\sum_{a=0}^{7} N_{a,t} c_{a,t}}_{C_t} + \underbrace{K_{t+1} - (1-d) K_t}_{I_t} + \underbrace{\vartheta_t Y_t}_{G_t}$$

where C_t, I_t and G_t respectively stand for aggregate private consumption, investment in physical capital and government consumption and K_t^* represents the asset holdings brought into the country by migrants and is given by

$$\text{(A20)} \quad K_t^* \equiv (1+r_t) \sum_{a=1}^{8} s_{a-1,t-1} \left(N_{a-1,t-1} - N_{0,t-a} \beta_{a-1,t-1} \right)$$

where the term in parentheses is the flow of migrants between date t and date t–1. To avoid modelling the specific behaviour of migrants over their life, we consider that they enter the country with an asset level $s_{a,t-1}$ given by (A5) and (A6), i.e. equivalent to that of natives of the same age.

The labour market equilibrium equalises the demand for labour from firms – L_t, E_t and H_t – to the sum of the individual supplies:

$$\text{(A21)} \quad L_t = \sum_{a=0}^{7} N_{a,t} l_{a,t} \; ; \qquad E_t = \sum_{a=0}^{7} N_{a,t} l_{a,t} e_{a,t} \; ; \qquad H_t = \sum_{a=0}^{7} N_{a,t} l_{a,t} h_{a,t} \; .$$

Definition 1 (Competitive equilibrium). *Given a demographic structure summarised by* $\{N_{a,t}\}_{a=0\ldots7,t\geq0}$, *an initial distribution of education* $\{u_{-j}\}_{j=1\ldots4}$ *and wealth* $\{s_{j-1,-1}\}_{j=1\ldots7}$, *a competitive equilibrium is*

- *a vector of individual variables* $\{c_{a,t},u_t,l_{a,t},e_{a,t},h_{a,t}\}_{a=0\ldots7,t=a\ldots\infty}$ *such that utility (A3) is maximised subject to constraints (A4), (A8), (A9), (A10) and (A11);*
- *a vector of individual variables* $\{c_{a,0},l_{a,0},e_{a,0},h_{a,0}\}_{a=1\ldots7,t=0\ldots7-a}$ *such that utility (A3) of the first old generations is maximised subject to constraints (A7), (A8), (A9), (A10) and (A11);*
- *a vector of firms' variables* $\{K_t,L_t,E_t,H_t\}_{t\geq0}$ *such that profits (A14) are maximised subject to technology (A12) and (A13);*
- *a vector of taxes* τ_t^w *balancing the budget of the government (A15);*
- *a vector of contingent prices* $\{p_{a,t+a}, \eta_{a,t+a}^L, \eta_{a,t+a}^E, \eta_{a,t+a}^H\}_{a=0\ldots7,t\geq0}$ *such that the no-arbitrage conditions (A17) and (A18) hold;*
- *a vector of interest factor and gross wages* $\{r_t, w_t^L, w_t^E, w_t^H\}_{a=0\ldots7,t\geq0}$ *such that the goods and labour markets are in equilibrium, i.e. (A19) and (A21) hold, and*

(A22) $$K_0 = \sum_{a=1}^{8} N_{a,0} s_{a-1,-1} - D_0$$

for the first period.

A7. Optimality conditions

Since there is no disutility of labour, the problem for individuals is separable.

- Individuals first maximise the expected value of income – the right-hand side of (A4) – with respect to educational investment u_t.
- Then, in a second step, they maximise the expected utility function and select the optimal contingent plan subject to the budget constraint in which the education investment is set to its optimal value.

The optimal education investment is given by

(A23) $$u_t^* = \left(\frac{\varepsilon\psi \sum_{a=1}^{4} \eta_{a,t+a}^{H} q_{t+a} l_{a,t+a}}{\left(1 - v_t\right) q_t \left(\eta_{0,t}^{L} + \eta_{0,t}^{H}\right) + \sum_{a=1}^{4} \eta_{a,t+a}^{E} \theta_e^{a} q_{t+a} l_{a,t+a}} \right)^{\frac{1}{1-\psi}} .$$

Maximising utility with respect to the levels of consumption determines the law of motion of contingent consumption expenditures over the lifetime:

(A24) $$c_{a+1,t+a+1} = \frac{\left(1 + r_{t+1}\right)\left(1 + \tau_t^{c}\right)}{1 + \tau_{t+1}^{c}} c_{a,t+a}, \quad a = 0,...,6 .$$

Substituting (A23) and (A24) into the budget constraint (A4) gives the optimal level of consumption in the first period of life. The aggregated consumption at period t then amounts to $C_t = \Sigma_a N_{a,t} c_{a,t}$.

The profit maximisation by firms requires the equality of the marginal productivity of each factor to its rate of return. They may be written as

(A25) $$r_t = \left(1 - \varphi\right) A_t Y_t / K_t - d$$

(A26) $$w_t^{L} = \varphi\left(1 - \delta\right) A_t Y_t / L_t$$

(A27) $$w_t^{E} = \varphi\delta\mu A_t K_t^{1-\varphi} Q_t^{\varphi-1} L_t^{1-\delta} E_t^{\rho-1} \left[\mu E_t^{\rho} + \left(1 - \mu\right)\Theta_t H_t^{\rho}\right]^{\delta/\rho-1}$$

(A28) $$w_t^H = \varphi\delta\left(1-\mu\right)\Theta_t A_t K_t^{1-\varphi} Q_t^{\varphi-1} L_t^{1-\delta} H_t^{\rho-1}\left[\mu E_t^\rho + \left(1-\mu\right)\Theta_t H_t^\rho\right]^{\delta/\rho-1}.$$

Given the hypothesis of constant returns to scale, national product is equal to the sum of capital income and labour income:

(A29) $$Y_t = \left(r_t + d\right)K_t + \left(w_t^L L_t + w_t^E E_t + w_t^H H_t\right).$$

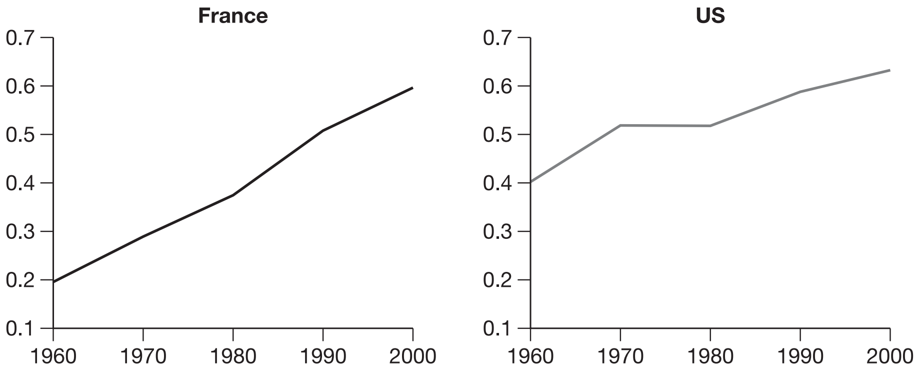
Appendix B. Education and participation rate data

For France, the time invested in education is computed using school attendance measures for the population aged 15–24 reported in Estrade and Minni (1996). Our corresponding estimates, as depicted in Figure B1, amount to 20 per cent in 1960, 28.9 per cent in 1970, 37.5 per cent in 1980, 51 per cent in 1990 and 59.8 per cent in 2000. For the US, we use the data and projections on educational attainment from Cheeseman Day and Bauman (2000). Given the skill structure of the population aged 25–34 between 1950 and 2000, we compute the time investment in education of successive cohorts. This gives 24.7 per cent in 1940, 31.8 per cent in 1950, 40.5 per cent in 1960, 52.2 per cent in 1970, 52.1 per cent in 1980, 59.1 per cent in 1990 and 63.5 per cent in 2000.

The old-age participation rate α is computed using the effective retirement age data from Blondal and Scarpetta (1997). Figure B2 presents the data for women and men. We use the average of the two.

FIGURE B1

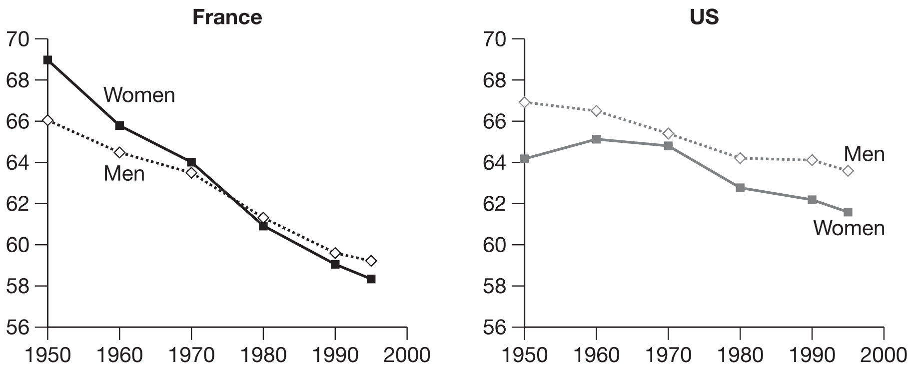
Education investment[a]



[a]Education investment is measured by the proportion of time devoted to education between the ages of 15 and 24.

FIGURE B2

Effective retirement age



Appendix C. Public finance data

Three proportional taxes are introduced in our model – the labour income tax, the capital income tax and indirect taxes. For France, the indirect tax rate and the rate of tax on capital income are estimated by Carey and Tchilinguirian (2000) at 18 per cent and 24 per cent respectively for 1995. The labour income tax rate is endogenous in the model but needs a target value: it has been estimated by Eurostat (1999) at 44 per cent in 1995. For the US, we calibrate these tax rates in such a way that the shares of revenues in GDP correspond to the estimations of Gokhale, Page and Sturrock (1999), i.e. 8 per cent for labour income taxes, 7 per cent for indirect taxes and 5 per cent for capital income taxes in 2000.

In our simulations for France, we consider that the tax rate on consumption expenditures increases linearly from 10 per cent in 1940 to 18 per cent in 1990 and that the tax rate on capital income increases from 15 per cent to 24 per cent over the same period. For the US, we assume that the indirect tax rate rises from 8 per cent to 14 per cent and that the capital income tax rate rises from 10 per cent to 28 per cent.

We distinguish two types of government spending (net of debt charges) – non-age-specific public consumption and age-specific transfers. For the composition of these categories, we build on Crettez, Feist and Raffelüschen (1999) for France and Gokhale, Page and Sturrock (1999) for the US. The history of non-age-specific spending is based on OECD data for the period 1960–95. We assume a constant share in GDP for future years, i.e. 11 per cent for France (excluding education) and 14 per cent for the US (including non-tertiary education). For age-specific transfers, we use age profiles computed for generational accounting exercises. The French profile is taken from Crettez, Feist and Raffelüschen (1999) and includes welfare benefits such as pensions, housing, the RMI (*Revenu Minimum d'Insertion*) programme, child and youth support, healthcare, education and other transfers. The US profile is taken from Gokhale, Page and Sturrock (1999) and includes OASDI (Old Age, Survivors and Disability Insurance), Medicare and Medicaid, tertiary education and other transfers. We incorporate a negative term capturing some taxes (of relatively small amount) that are not explicitly modelled, such as the property tax and seigniorage revenue. These age-specific transfers are increasing with age. They are usually more important in France than in the US, especially for individuals aged 55 and over.

Social security benefits and other individual transfers evolve exogenously. Between 1960 and 2000, their levels are rescaled proportionally so as to reproduce the time path of public transfer and pension shares in GDP (as reported by the OECD). For future decades, these transfers are adjusted so as to keep the share in GDP constant.

Between 1900 and 2000, the public debt/GDP ratio is exogenously set to its observed value. Observations are taken from OECD statistics for the period 1985–2000. For previous periods, we use data from the French Treasury Department for France and from Brown (1990) for the US. For future decades, we assume that the debt ratio is constant.

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