A Tale of Two Countries: A Story of the French and US Polarization

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Abstract

This study investigates job polarization in the United States and in France. In the data, the dynamics of employment *shares* for abstract, routine, and manual jobs appear very similar in the two countries. This similarity actually hides major differences in the dynamics of employment *levels* by tasks. In particular, the routine employment level fell significantly in France until the mid-1990s, and then rebounded until 2007. The evolution of US routine employment went in opposite directions to that of the French economy. We then develop a multi-sectorial search and matching model with endogenous occupational choice to disentangle the respective contributions of task-biased technological change (TBTC), labor market institutions (LMI), and rising educational attainment to job polarization. For the US economy, we find that TBTC and the rising supply of skilled labor are the main drivers of polarization in a context of growing employment levels. In France, in contrast, polarization is driven mainly by LMI changes. This led to a sharp drop in routine employment in a context of declining aggregate employment until the mid-1990s, which then reversed when the impact of the minimum wage was alleviated by a subsidy policy targeted at low wage earners. Next, we quantify the welfare consequences of job polarization. Abstract and manual workers are the main winners of job polarization in both countries. Welfare gains and losses are more dispersed in the routine group. The most productive French routine workers would have been worse off without LMI changes. In contrast, displaced low-ability, routine French workers would have preferred a more flexible labor market to improve their employment prospects in their occupational change. All US routine workers suffered as a result of the drop in LMI generosity.

Keywords: Search and matching, job polarization, labor market institutions.

JEL Classification: E24, J62, J64, O33

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1 Introduction

Job polarization seems to be a common feature of developed economies. Over the last 30 years, employment growth has been fast, not only in high-paid jobs (abstract, non-routine, cognitive tasks requiring creativity, problem-solving), but also in low-paid jobs (manual, non-routine job requiring human interaction, service occupation). Employment growth has decreased significantly among middling jobs (routine, repetitive, specific activities accomplished by following well-defined instructions and procedures), and those involving tasks that can be replaced by machines (Autor & Dorn (2013); Goos et al, 2009, 2014). The aim of this study is to compare the polarization process between the United States and France, because they differ greatly with respect to their labor market adjustments. Indeed, French labor market institutions (hereafter, LMI) evolved towards a more rigid labor market (increasing minimum wage, unemployment benefits, workers' bargaining power). In contrast, the United States started the technological transition with a more flexible labor market, and increased flexibility even further (with opposite evolutions of minimum wage, unemployment benefits and unionization).

What are the driving forces behind job polarization? To this day, the literature has focused on task-biased technological change (hereafter, TBTC). However, other phenomena occurred during the same period, namely changes in LMI and the rise in the supply of educated workers. Our study is the first to analyze to what extent TBTC, labor supply, and LMI interact to shape polarization. We illustrate these interactions by comparing the US and French economies. Because polarization involves sizeable reallocations and mobilities on the labor market, it is likely to produce quite different performances, depending on wage and employment rigidities, which are shaped by LMI. In addition to the policy-shock interactions, LMI may also dominate the impact of TBTC and give rise to a different polarization in terms of its modalities and consequences for employment and welfare.

We first examine job polarization using US and French data. The dynamics of employment *shares* for abstract, routine, and manual jobs appear similar across the two countries, which is consistent with the findings of Goos et al. (2009). However, this apparent similarity hides major differences in the dynamics of employment *levels* by tasks. In particular, the routine employment level actually fell in France until the mid-1990s, and then rebounded until 2007. The evolution of US routine employment went in an opposite direction to that of the French economy. The first wave of US polarization before the beginning of the 2000s was an increase in abstract jobs and, to a lesser extent, in manual jobs, instead of a decline in the number of routine jobs. This explains the different pattern in aggregate employment levels before 2000, with employment rising in the United States and declining in France. Since this date, the opposite trend in routine employment in both countries is still the key feature explaining aggregate employment and employment by task. Employment levels are more informative while employment shares may give rise to a misleading interpretation about job polarization. We question the analysis of polarization in terms of employment share, and argue that studying employment levels is the correct approach. Moreover, what matters for welfare is the employment level, not the employment share.

We develop a multi-sectorial search and matching model with endogenous occupational choice to examine the way TBTC, LMI, and educational attainment affect polarization. This question involves so many economic interactions that it cannot be addressed using a purely empirical approach. Only counterfactual experiments in a quantitative modeling approach can provide meaningful answers. Here, Autor & Dorn (2013) meet Mortensen & Pissarides (1994) (hereafter, MP). Our work bridges the gap between two strands of literature. The first strand of literature, in the wake of MP seminal work, tries to identify the reasons behind the low employment level in Europe compared to that in the United States (the so-called "European employment problem," (Ljungqvist & Sargent (1998), Ljungqvist & Sargent (1998)). Since the empirical works of Blanchard & Wolfers (1999), this literature emphasizes the role of LMI (in interaction with aggregate shocks) in shaping transatlantic differences in employment rates, and the role of structural reforms in improving European employment levels. The second strand of literature (Autor & Dorn (2013), Acemoglu & Autor (2011), Autor et al. (2003), Barany & Siegel (2017)) deals with the employment structure and the dynamics of wages across skill groups as the outcome of task-biased technical progress. Unlike Autor & Dorn (2013), we propose a model with labor market frictions, where there is no full employment in the unskilled and skilled labor markets.

The impact of technological changes have already been explored in the search and matching literature (Mortensen & Pissarides (1998); Hornstein et al. (2007)). We extend these works by emphasizing transitional dynamics (rather than the steady state). In addition, along the transitional path, we document the interaction between technological change, labor market institutions, and occupational choices. Our welfare results illustrate the need for a careful analysis of transitional dynamics in order to shed light on the unequal sharing of the benefits of technological changes. Occupational choices have also been explored in the search and matching literature (Alvarez & Shimer (2011); Carrillo-Tudela & Visschers (2014)). We extend their work by considering occupational changes in a context of technological change, rather than from a business cycle perspective. This significantly alters the theoretical analysis, because occupational decisions are made in a non-stationary environment. In particular, in our model, occupational mobility refers to flows toward the *bottom* of the wage distribution, where employment opportunities are expanding. In our model, workers are heterogeneous across and within tasks, which allows for a clear identification of the winners and losers of job polarization. Finally, in both strands of literature, the supply of skilled labor is usually fixed. We relax this assumption and explore the quantitative implications of an increasing supply of skilled labor (as observed in the data). [1]

The model is calibrated using French and US data to match the main structural changes in the shares and levels across tasks. Given the good fit of the model, we use it to understand the evolution of employment levels and shares observed in the past decades in France and in the United States. We compute their counterfactual evolutions without technological change, better educated labor supply, or LMI changes, thereby quantifying the contribution of each

[1] In our model, the increase in educational attainment is exogenous. Barany (2016) studies the endogenous response of skill choices and technological changes to the fall in the US minimum wage. We focus on the interaction between educational attainment, technology, and LMI in the United States, as in Barany (2016). The endogenous response of educational attainment is beyond the scope of this study, and is left for future research. With respect to the work of Barany (2016), we study the impact of other LMI, beyond the minimum wage. Here, we uncover the leading role in de-unionization in the US polarization process. We also consider a search and matching model, while Barany (2016) discards matching frictions. In addition, we investigate another country in order to emphasize that job polarization differs across countries.

element to the evolution of polarization. We find quite different underlying factors for the apparently similar polarization in the United States and France. In the United States, we find that TBTC and the rising labor supply of educated workers are the main contributors to polarization in a context of increasing aggregate employment level. Without TBTC or without rising educational attainment, US employment gains since the early 1980s would have been 40% lower. In France, polarization is the result of a combination of educational attainment and LMI dynamics. This second component cannot be ignored because it appears to be the main driver of polarization in the French case: a sharp drop in routine employment in a context of declining aggregate employment, and then a reverse evolution when the impact of the minimum wage has been alleviated by a subsidy policy targeted at low wages. Without the expansion in educational attainment, French employment losses would have doubled. TBTC did impact French employment level. However, its macroeconomic effects have been overcome by changes in LMI and the supply of skilled workers.

As a second step, we quantify the welfare consequences of job polarization. Worker heterogeneity across and within tasks allows for rich welfare predictions. Abstract and manual workers are the main winners of job polarization in both countries. Welfare gains and losses are more dispersed in the routine group. We find that the most productive American routine workers would have been better off without the de-unionization that reduced their share of the gains from technological changes. This may explain why some American workers do not support technological changes: they do not receive a sufficient share of the associated surplus. In contrast, French low-ability routine workers would have preferred a more flexible labor market to improve their employment prospects in their occupational change. Our results can explain why the recent wave of populism observed in the United States and in France has not produced the same electoral results. Indeed, it can be linked to the economic changes in the labor market.[2] In the United States, TBTC has excluded the most fragile routine workers, these workers are forced to choose a costly reallocation towards manual jobs. At the same time, the deregulation of the US labor market has reduced the share of the labor surplus captured by routine workers who remain in routine jobs along the technological transition, because they are high-ability workers. In France, the jobs of the middle class were destroyed because labor market rigidities have increased, which occurs before the beginning of TBTC. The additional problem in France is that these rigidities stall reallocations towards manual jobs. For voters, the best answer could be to ask for better protection in the United States, which is perhaps what is perceived in Trump's program, and more flexibility in France, which is suggested in Macron's program.

We present out data in Section 2, the model in Section 3 and the calibration and estimation strategy in section 4. We compare two countries: the United States and France. In section 5, we quantify the respective contribution of TBTC, changes in LMI, and rise in the supply of skilled labor in the understanding of the evolution of aggregate employment and employment shares in the past decades. The impacts on welfare are reported in section 6. Section 7 concludes the paper.

[2]See Autor et al. (2016) for a more formal test on the link between the electoral consequences of labor market changes in the United States.

2 Data analysis: Beyond apparently similar polarization

Goos et al. (2009) show that employment shares by task (defined as employment in task i divided by aggregate employment) display similar evolutions in developed countries, including France and the United States: a drop in the share of routine jobs and a rise in the shares of manual and abstract jobs in total employment. In this section, we consider each element of the ratio. A close look at the separate evolutions of the numerator and the denominator reveals divergent stories behind the apparent common polarization. In particular, we argue that the decline in routine employment share is actually driven by the higher increase in aggregate employment levels, as in the US case before the mid-1990s or France after the mid-1990s.

2.1 Employment share by task: Pervasive job polarization

Figure 1 reports the evolution of employment shares in the United States and France for abstract, routine, and manual jobs. We use annual CPS US data and French Labor Force Surveys from 1983 to 2007.[3] Total employment is then disaggregated by occupational group, as in Jaimovich & Siu (2012). Based on the employment shares by task, job polarization seems pervasive in the United States and in France, with a rising employment share of manual service jobs and abstract jobs, along with a fall in routine jobs. The share of routine employment has decreased continuously, with a fall of about 10 percentage points in both countries since the early 1980s. The shares of abstract and manual jobs increased in both countries, by approximately 8 and 2 percentage points, respectively.

2.2 Divergent changes in employment levels across countries

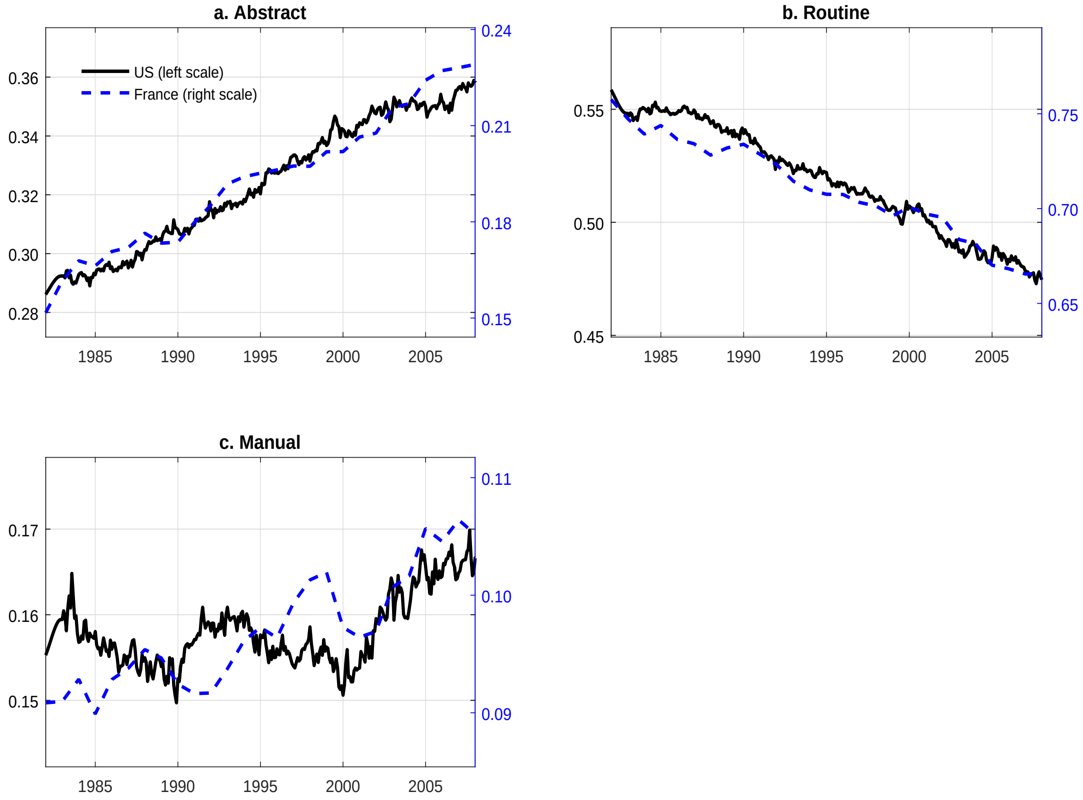
Aggregate employment. Aggregate per capita employment (defined as the number of all employed civilian non-institutionalized individuals aged 16 years and over, divided by the population) [4] has evolved very differently, with a striking rise in the United States, and a downward trend in France until the mid-1990s followed by a rebound (Figure 2, panel d.).

Routine employment. The number of routine jobs in the population followed opposite dynamics in the two countries (Figure 2, panel b.). In France, from the early 1980s to the mid-1990s, there has been a sharp decline in employment of about 5 percentage points. Over the same period, the decline was limited in the United States. Thus, the falling share of routine jobs depicted in Figure 1 does not have the same cause: in the United States, it comes mainly from the increase in aggregate employment due to job creation in abstract and manual tasks. In France, the decrease in routine employment share is first the outcome of the fall in routine per capita employment, which led to a decline in aggregate employment.

[3] We discard data during the financial crisis because we do not include financial shocks in the model.

[4] This ratio is commonly referred to as the "employment rate." However, in the text, we refer to this ratio as "per capita employment," "employment *level*," or "employment," as opposed to the "employment *share* of task i," defined as the number of employed individuals in task i divided by the total number of employed individuals.

Figure 1: Employment Share by Task



Employment level by task divided by aggregate employment. US data from the Bureau of Labor Statistics, Current Population Survey, and French Labor Surveys. See Appendix A for details.

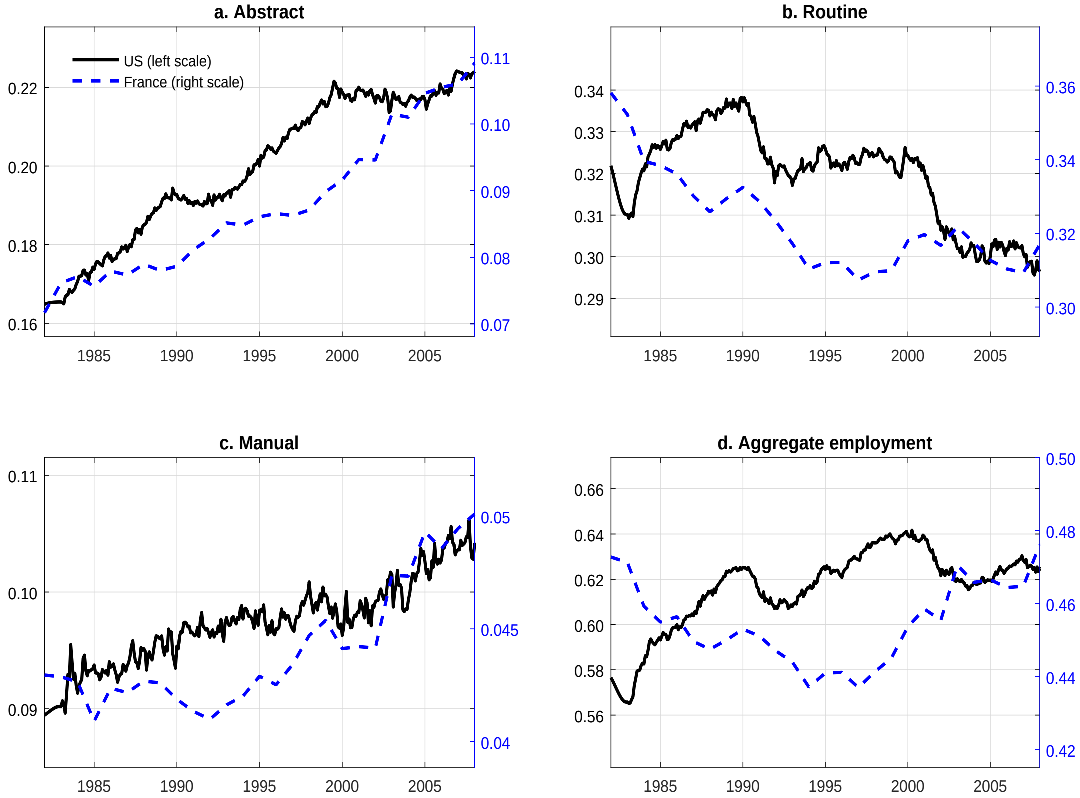
In contrast, after 1995, per capita routine employment in France rebounded: aggregate employment increased in France, because routine per capita employment stabilized, abstract employment accelerated, and manual jobs started to increase. In the United States, routine per capita employment declined sharply, causing aggregate per capita employment to fall.[5]

Manual employment. The limited increase in manual employment share in both countries does not have the same meaning when changes in employment levels are taken into account. Given the rapid rise in US aggregate employment in the 1980s and 1990s, this apparently limited increase actually involves large labor reallocations from routine to manual jobs. The quasi constancy of the share of manual employment seems to contradict the idea of polarization (Figure 1, panel c.), but it must be interpreted in a context of increasing aggregate employment. There is indeed an increase in the number of manual jobs in the population (Figure 2, panel c.), but at a much lower rate than that of abstract jobs. The increase in the supply of skilled workers makes this increase in the share of manual tasks even more remarkable.

In contrast, the increasing share of workers in manual occupations in France might just be

[5]We show in Appendix B that divergent evolutions of routine employment is the main driver of the divergent employment levels across countries.

Figure 2: Per capita employment by task



Employment level by task divided by aggregate population. US data from the Bureau of Labor Statistics, Current Population Survey, and French Labor Surveys. See Appendix A for details.

mirroring a mere mechanical effect of the fall in aggregate employment due to routine jobs: constant levels of jobs in manual tasks (Figure 2, panel c.) are enough to lead to a rise in employment share (Figure 1, panel c.).

In summary, what could have been first considered a similar polarization process, based on the dynamics of employment shares, changes with a deeper analysis of employment levels. US polarization, until the early 2000s, is first an increase in abstract jobs and, to a lesser extent, of manual jobs rather than a decline in the number of routine jobs. French polarization is basically the opposite. This explains the opposite pattern in aggregate employment levels before 2000. After this date, opposite trends in routine employment are still the key features behind the structural changes and the aggregate employment, much more than a simple investigation of the share dynamics reveal. Under the assumption that technological progress is roughly the same in both countries, the polarization of employment shares is driven by other forces. Overall, these results raise questions about the analysis of polarization in terms of shares, and calls for an analysis based on employment levels.

3 The model

The model is a dynamic general equilibrium model with search and matching frictions, featuring workers' endogenous occupational choices. The exogenous drifts are an exogenous task-biased technological change (TBTC), a long-run rising trend in educational attainment, and shifts in LMI. In order to make the model tractable, we abstract from financial markets, as in Autor & Dorn (2013).

3.1 Assumptions

As in Autor & Dorn (2013), the economy consists of two sectors: goods and services.[6] The goods sector uses three inputs: *(i)* high-skilled workers in abstract jobs L_a, *(ii)* unskilled workers employed in routine tasks L_r, and *(iii)* computer capital K (equipment, computers, machine). Technological change is captured by an exogenous downward trend in the price of computers p_K. The service sector employs only unskilled labor in manual tasks L_m.

The labor supply consists of skilled and unskilled workers.[7] Skilled workers are homogeneous and all perform abstract tasks. There is a continuum of unskilled workers who differ with respect to their abilities η. Unskilled unemployed workers previously occupied on a routine job can choose to switch to service occupation. Low-skill workers have homogeneous (heterogeneous) skills at performing manual (routine) tasks.[8] We depart from Autor & Dorn (2013) by considering the upward exogenous trend in educational attainment (as observed in the data), which shifts the relative labor supply of skill labor. This phenomenon is driven mainly by the rise in educational attainment, at the end of schooling, or training programs inside firms, which are choices beyond the scope of this study: hence, the reallocation from unskilled to skilled labor force is exogenous.[9]

[6] In this paper, we will use the term "service" as a shortcut for "service occupation," which employs only unskilled workers in manual tasks.

[7] See Appendix C for a graphical presentation of the model.

[8] This feature is also in Autor & Dorn (2013) and is consistent with the view that blue-collar workers in a factory differ in performing their tasks on the assembly line, while jobs such as janitors rarely differ in terms of productivity in providing non-routine manual services. Thus, the model proposes a stylized mapping of skills and jobs. The data might suggest that the real world involves more complex mobility. However, we argue that our stylized model captures the salient mobility involved in job polarization and changes in aggregate employment.

[9] Endogenous mobility across tasks in the model might seem limited with respect to the possible real-life mobilities. However, first, we consider the same mobilities as in Autor & Dorn (2013). For the sake of clarity, we propose an extension of Autor & Dorn (2013)'s model to include LMI and the drift in educational attainment. Second, we consider mobilities from routine to abstract workers through the exogenous increase in educational attainment. Finally, the mobilities discarded in the model are not a significant part of the data. Carrillo-Tuleda et al. (2016) estimate the transition matrix for workers changing careers across occupations using UK data. For high-skill workers, approximately 80% remain in their occupation from one year to the next. Mobility from routine or manual jobs to abstract jobs lies below 10% each year.

3.2 Labor market frictions

Skilled workers are employed in abstract tasks (a). Unskilled workers can be employed either in routine tasks (r) or in manual tasks (m). When fired from a good-producing firm, routine unemployed workers can choose to switch occupation (we call them *new movers*, indexed by m^n) and join the pool of unemployed workers looking for manual jobs. Routine workers who remain in the routine pool are called "stayers." New movers differ from other unemployed workers looking for a manual job because *(i)* their unemployment benefit depends on their past wages as routine workers, *(ii)* they must learn to work in manual occupations, which means their productivity on manual tasks is lower than that of experienced manual workers. These new movers can become old movers (indexed by m^o) who switched occupation from routine to manual jobs, got short-term work experience as a manual worker, and got fired (hence their unemployment benefits are indexed on manual wage), but have not yet found a regular manual job (so that they are not as productive as experienced manual workers are). The slow learning process (with respect to the duration of eligibility to unemployment benefit) and the indexation of unemployment benefits on past wage lead us to create this category of "old movers."

Labor markets are characterized by search and matching frictions, *à la* Mortensen & Pissarides (1994). A search is directed because there is a labor sub-market for each occupation and for each ability level η in routine jobs. Within each pool, the meeting process between workers and firms is random. There is no on-the-job search. Then, M_t, the number of the hiring per period, in each segment of the labor market (abstract, routine for each ability level η, and all manual labor), is determined by a constant returns to scale matching function:

$$M_i = \Upsilon_i V_i^{\psi} U_i^{1-\psi}, \quad \text{for task } i = a, m, m^o \text{ and } \; M_i(\eta) = \Upsilon_i V_i(\eta)^{\psi} U_i(\eta)^{1-\psi}, \quad \text{for } i = r, m^n \tag{1}$$

where $\Upsilon_i > 0$ is a scale parameter measuring the efficiency of the matching function, V is the number of vacancies, and U the number of unemployed workers at time t in each submarket. Then, $0 < \psi < 1$ is the elasticity of the matching function with respect to vacancies. A vacancy is filled with probability $q_i = M_i/V_i$, and the job finding probability per unit of worker search is $f_i = M_i/U_i$. The labor market tightness is measured by the ratio V_i/U_i.

A job can be destroyed for exogenous reasons at rate s_i. Endogenous separations occur in our model because some firms incur negative profits when the wage is equal to the minimum wage: this defines a scrapping-time, after which the firm shuts down.

3.3 Workers' value functions, occupational choices

For abstract and routine workers, the value functions[10] are

$$\mathcal{W}_a = (1-\tau^w)w_a + \beta[(1-s_a)\mathcal{W}_{a,+1} + s_a\mathcal{U}_{a,+1}] \tag{2}$$
$$\mathcal{W}_r(\eta) = (1-\tau^w)w_r(\eta) + \beta[(1-s_r)\mathcal{W}_{r,+1}(\eta) + s_r \max\{\mathcal{U}_{r,+1}(\eta), \mathcal{U}^n_{m,+1}(\eta)\}] \tag{3}$$

[10]For the sake of parsimony, we drop the time subscript for contemporaneous variables. Expected variables are assigned a subscript +1.

For manual workers, we distinguish between three types of workers: the experienced manual worker ($\mathcal{W}_m$); the inexperienced manual worker entitled to an unemployment benefit, indexed by the wage of a routine job ($\mathcal{W}_m^n$); and the experienced manual worker entitled to an unemployment benefit, indexed on the wage of a manual job ($\mathcal{W}_m^o$). The value functions are:

$$\begin{aligned}
\mathcal{W}_m &= (1-\tau^w)w_m + \beta[(1-s_m)\mathcal{W}_{m,+1} + s_m\mathcal{U}_{m,+1}] && (4)\\
\mathcal{W}_m^o &= (1-\tau^w)w_m^o + \beta\lambda[(1-s_m)\mathcal{W}_{m,+1} + s_m\mathcal{U}_{m,+1}]\\
&\quad +\beta(1-\lambda)[(1-s_m)\mathcal{W}_{m,+1}^o + s_m\mathcal{U}_{m,+1}^o] && (5)\\
\mathcal{W}_m^n(\eta) &= (1-\tau^w)w_m^n(\eta) + \beta\lambda[(1-s_m)\mathcal{W}_{m,+1} + s_m\mathcal{U}_{m,+1}]\\
&\quad +\beta(1-\lambda)[(1-s_m)\mathcal{W}_{m,+1}^n(\eta) + s_m\mathcal{U}_{m,+1}^o], && (6)
\end{aligned}$$

τ^w denotes the tax rate for social contributions. For unemployed workers, the value functions are:

$$\begin{aligned}
\mathcal{U}_a &= z_a + \beta[(1-f_a)\mathcal{U}_{a,+1} + f_a\beta\mathcal{W}_{a,+1}] && (7)\\
\mathcal{U}_m &= z_m + \beta[(1-f_m)\mathcal{U}_{m,+1} + f_m\mathcal{W}_{m,+1}] && (8)\\
\mathcal{U}_r(\eta) &= z_r(\eta) + \beta[(1-f_r(\eta))\max\{\mathcal{U}_{r,+1}(\eta), \mathcal{U}_{m,+1}^n(\eta)\} + f_r(\eta)\mathcal{W}_{r,+1}(\eta)] && (9)\\
\mathcal{U}_m^o &= z_m + \beta[(1-f_m^o)\mathcal{U}_{m,+1}^o + f_m^o\mathcal{W}_{m,+1}^o] && (10)\\
\mathcal{U}_m^n(\eta) &= z_r(\eta) + \beta[(1-f_m^n(\eta))\mathcal{U}_{m,+1}^n(\eta) + f_m^n(\eta)\mathcal{W}_{m,+1}^n(\eta)] && (11)
\end{aligned}$$

Equation (2) refers to the value of employment for an abstract worker, where w_a is the associated wage and $\mathcal{U}_{a,+1}$ is the value of unemployment in the next period. Equation (4) is the equivalent for workers in the manual sector. In the worker's value of employment (Equation (3)), the occupational choice is captured by the term $\max\{\mathcal{U}_{r,+1}(\eta), \mathcal{U}_{m,+1}^n(\eta)\}$ when unemployed. For unskilled workers, the η-type matters: the endogenous segmentation of the labor market determines the threshold $\widetilde{\eta}$, such that for $\eta < \widetilde{\eta}$, workers are in the market of manual tasks, but are in the labor market of routine tasks for $\eta \geq \widetilde{\eta}$. The exogenous task-specific destruction rates s_i regulate the pace at which workers face the opportunity of switching occupation. If routine workers switch occupation when unemployed, they join the pool of unemployed workers looking for a manual job. Within this pool, we have to distinguish between three groups. The first group are "regular" job seekers who were fired from a manual job (Equation (8)) and receive unemployment benefits z_m. The second group are new movers, who just joined the pool after being fired from a routine job. They then receive unemployment benefits based on their past occupation and ability η ($z_r(\eta)$ in equation (11)), which affects their bargained wage when they find a job in the manual sector ($w_m^n(\eta)$ in equation (6)). The third group are old movers, who are routine workers who switched to manual jobs, had access to one manual job, got fired from this manual job, and now receive unemployment benefits (z_m in equation (10)). Their bargained wage w_m^o does not depend on their ability level η. They are not as productive as experienced manual workers.

For tractability reasons, we use a directed search such that each type of unemployed worker in the pool (Equations (8), (10), and (11)) has a corresponding job value (Equations (4), (5), and (6)). All movers, whether old or new, can get a regular manual job with probability λ. This regulates the pace of the learning process from routine workers who switched occupation and are not fully informed about the new tasks and vacancies in the manual sector. This is consistent with the view that an important component of human capital is task and occupation specific (Poletaev & Robinson (2008), Kambourov & Manovskii (2009), Cortes (2015)), which is lost by the worker who switches tasks.

3.4 Good-producing firm

We assume the same production function as in Autor & Dorn (2013). However, because of wage bargaining for skilled and unskilled workers, we need to preserve the constant return to scale in the bargaining process. As a result, we present the good-producing firm as using two separate inputs: Z_1 paid at price $_{z1}$ is produced by abstract workers L_a, and Z_2, paid at price p_{z2} is the aggregate of unskilled labor and capital. The good-producing firm's problem is

$$\begin{aligned} \Pi_g &= \max \{Y_g - p_{z1}Z_1 - p_{z2}Z_2\} \\ \text{s.t. } Y_g &\leq AZ_1^{\alpha}Z_2^{1-\alpha} \end{aligned}$$

The behavior of the firms producing intermediate good Z_1 is

$$\begin{aligned} \Pi_{z1} &= \max \left\{ p_{z1}Y_{z1} - (1+\tau_h^f)w_aL_a - c_aV_a + \beta\Pi_{z1,+1} \right\} \\ \text{s.t. } Y_{z1} &\leq L_a \\ L_{a,+1} &= (1-s)L_a + q_aV_a, \end{aligned}$$

where τ_h^f denotes the payroll tax rate for high-skilled workers. For high-tech firms, the production function Y_{z1} is a linear function (Equation (12)), and firms pay a search cost to hire new workers: c_a is the cost of posting a vacancy for an abstract job.

The behavior of the firms producing intermediate goods Z_2 is

$$\Pi_{z2} = \max \left\{ \ p_{z2}Y_{z2} - p_kK - (1+\tau_l^f)\sum_\eta w_r(\eta)L_r(\eta) - c\sum_\eta V_r(\eta) + \beta\Pi_{z2,+1} \ \right\},$$

$$\begin{aligned} \text{s.t. } Y_{z2} &\leq \left[\left((1-\mu)\sum_{\eta^S}^{\overline{\eta}} \eta L_r(\eta) \right)^{\sigma} + (\mu K)^{\sigma} \right]^{\frac{1}{\sigma}} && (12) \\ L_{r,+1}(\eta) &= (1-s)L_r(\eta) + q_r(\eta)V_r(\eta) && (13) \\ V(\eta) &\geq 0 \qquad\qquad (\mu(\eta)), && (14) \end{aligned}$$

where Y_{z2} denotes the intermediate good production, τ_l^f is the payroll tax rate for low-skilled workers, K is the stock of computers, p_K is its price, and c is the cost of posting a vacancy. As in Autor & Dorn (2013), TBTC is modeled as an exogenous fall in p_K. Equation (12) is the production function with σ and $\mu \in (0,1)$. The elasticity of substitution between routine labor and computer capital is $\frac{1}{1-\sigma}$ and, by assumption, is greater than 1. Equations (13) and (12) capture the evolution of labor stock given the probability q of filling a vacancy V. Finally, equation (14) allows to distinguish between two regimes: the first where it is profitable for the firm to replace the exogenous separations ($V_r(\eta) > 0$), and the second, where it is optimal to voluntarily reduce its workforce ($V_r(\eta) = 0$).

3.5 Service-producing firm

The representative firm's problem is

$$\Pi_s = \max \left\{ \begin{array}{l} p_s Y_s - (1+\tau_l^f)\left(w_m L_m + \sum_\eta w_m^n(\eta) L_m^n(\eta) + w_m^o L_m^o\right) \\ -cV_m - c\sum_\eta V_m^n(\eta) - cV_m^o + \beta \Pi_{s,+1}, \end{array} \right\}$$

$$\begin{aligned} \text{s.t. } \; Y_s &\geq A_s \left(L_s + \delta \sum_\eta L_m^n(\eta) + \delta L_m^o \right) && (15) \\ L_{m,+1} &= (1-s)L_m + q_m V_m + (1-s)\lambda \sum_\eta L_m^n(\eta) + (1-s)\lambda L_m^o && (16) \\ L_{m,+1}^o &= (1-s)(1-\lambda)L_m^o + q_m^o V_m^o && (17) \\ L_{m,+1}^n(\eta) &= (1-s)(1-\lambda)L_m^n(\eta) + q_m^n(\eta)V_m^n(\eta), && (18) \end{aligned}$$

where $A_s > 0$ is a relative productivity parameter (with respect to a good). The service production function (equation (15)) uses low-skilled workers, including new and old movers: L_m, $L_m^n(\eta)$, and L_m^o. Here, δ captures the lower productivity of workers who switched occupation, and are not fully familiar with manual tasks. Note that p_s is the endogenous relative price of services relative to goods.

3.6 Job creation conditions and creation costs

We consider that firms are subject to a cost of advertising the vacant job (c_a or c). Job creation conditions are given by (See Appendix D.1).

$$\frac{\widetilde{c}}{\widetilde{q}} = \beta \widetilde{J}_{+1} \quad \text{with} \quad \left\{ \begin{array}{rcl} \widetilde{c} &=& c_a, c \\ \widetilde{q} &=& q_a, q_r(\eta), q_m, q_m^n, q_m^o \\ \widetilde{J}_{+1} &=& J_{a,+1}, J_{r,+1}(\eta), J_{m,+1}, J_{m,+1}^n, J_{m,+1}^o \end{array} \right. \qquad (19)$$

3.7 Wage setting

The wage is set to maximize the joint surplus from the match

$$w_{Nash} = \text{argmax}\,(J_i - \mathcal{V}_i)^{1-\gamma} (\mathcal{W}_i - \mathcal{U}_i)^\gamma \quad \text{with} \quad i = a, r, s, m, m^n, \qquad (20)$$

where $J - \mathcal{V}$ is the marginal value of a match for a firm and $\mathcal{W} - \mathcal{U}$ the marginal worker's surplus from the match. Then, γ denotes the worker's share of a job's value (i.e., worker's bargaining power). In the DMP model, Nash bargaining gives the WS (wage setting) curve: the wage is highly flexible and responds to changes in productivity and labor market tightness, but there is a minimum wage (MW) for each task that can disconnect the wage from the productivity. For all jobs, we have the following WS rule:

$$w = \max\{MW, w_{Nash}\},$$

using all Bellman equations $\mathcal{W}$,$\mathcal{U}$, $\mathcal{V}$, and J, and the free-entry conditions $\mathcal{V} = 0$. Workers take into account outside opportunities, which that include mobilities to other jobs.[11]

3.8 General equilibrium: Household preferences and demand for goods and services

We have several households in the model, one for each type of job and unemployment. All households share the same preferences. Their consumption basket C includes goods C_g and services C_s:

$$C = \left[\nu C_g^\rho + (1-\nu) C_s^\rho\right]^{\frac{1}{\rho}} \quad \text{with } \rho \in [0,1],$$

where $\frac{1}{1-\rho}$ is the elasticity of substitution between goods and services. For each worker, the budget constraint is

$$P\ C = I \quad \text{with income } I \in \{w_a, w_r(\eta), w_m, w_m^o, w_m^n, z_a, z_m, z_r(\eta), v\}.$$

The optimal sharing of the consumption basket good C is given by:

$$p_s = \frac{1-\nu}{\nu}\left(\frac{C_g}{C_s}\right)^{1-\rho} \quad \Rightarrow \begin{cases} C_g = \nu^{\frac{1}{1-\rho}} \left(\frac{1}{P}\right)^{\frac{1}{\rho-1}} \frac{I}{P} \\ C_s = (1-\nu)^{\frac{1}{1-\rho}} \left(\frac{p_s}{P}\right)^{\frac{1}{\rho-1}} \frac{I}{P} \end{cases} \tag{21}$$

which are the demand functions. The consumer price index is

$$P = \left[\nu^{\frac{1}{1-\rho}} + (1-\nu)^{\frac{1}{1-\rho}} (p_s)^{\frac{\rho}{\rho-1}}\right]^{\frac{\rho-1}{\rho}}. \tag{22}$$

For the sake of brevity, market clearing is reported in Appendix D.3.

4 Calibration

Calibration is a difficult task in this model. Indeed, we have a large number of parameters and exogenous trends, all the more so as we consider two countries. We need to choose which parameters are common to both countries, and which are country-specific. Furthermore, the calibration task is all the more complex as we want the model to capture employment *paths* over the sample, which implies that parameter values must make the model mimic the data *over*

[11] See Appendix D.2 for a complete description of the wage equations.

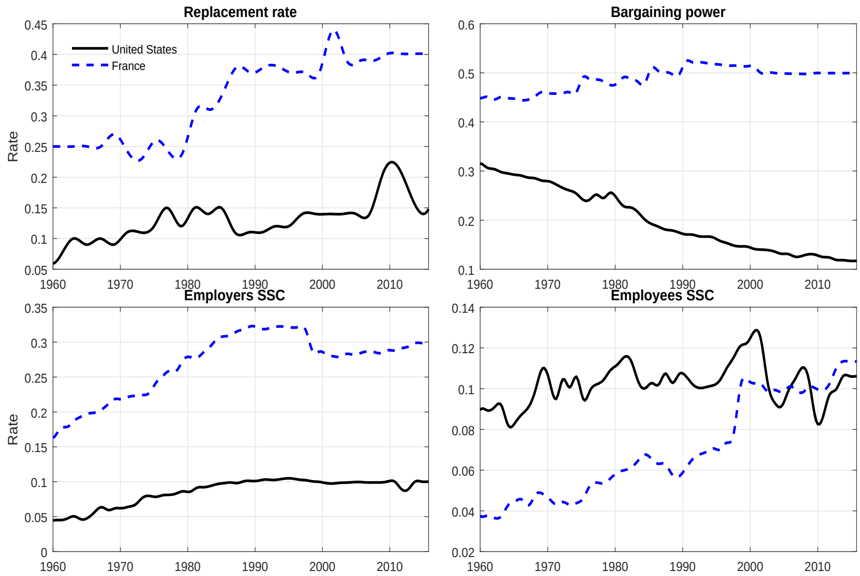
time, not historical averages, which is the standard procedure in the literature.[12] We therefore make the following choices. First, consumer preferences, technology, and distribution of abilities η (assumed to be uniform) within unskilled labor are the same across countries. Second, the empirical targets for the estimation include employment levels by task at the beginning of the technological transition, at the end of the sample, and the average level over the whole sample. Third, we feed the model with three exogenous trends. The first relates to TBTC, assumed to be common across countries (fall in the price of capital p_K). The other two are country-specific: rising educational attainment (L_a), and changes in LMI. We then need to decide which trends are estimated, which is calibrated. LMI shifts are taken from OECD data, while the fall in the price of capital and rising educational attainment are estimated. Indeed, p_K the price of capital in the model relates to computer capital. Estimations of ICT capital price are scarce (it must be available for both countries, since the early 1980s) and widely debated. We also estimate the rise in skilled labor. We choose to discard data on educational attainment as there is no one-to-one mapping between abstract occupations and workers' education: in the data, not all abstract workers have a college education, and some abstract workers have obtained their job after job-to-job mobility inside their firms. Because of this measurement gap between the data and the definition of "skilled-abstract" workers in the model, we choose to estimate the trend in L_a.

4.1 Divergent shifts in LMI: Rising flexibility in the United States, and rising rigidity in France

Shifts in LMI (Figures 3-5) are taken from the data and input into the model. After the early 1980s, the United States and France were characterized by opposite changes in the replacement rate and workers' bargaining power: they both increase in France, whereas, in the United States, the replacement rate is stable and workers' bargaining power declines. The two bottom panels of Figure 3 also underline the contrasting evolution of tax rates: until the mid-1990s, these tax rates largely increase in France, whereas in the United States they are stable over the whole period. Figure 3 also shows that the French employer SSC (or the payroll tax rate) falls sharply in the mid-1990s. During the 1990s, tax exemptions on employer-paid payroll taxes (τ^f) were introduced in France to lower labor costs. This policy aimed to offset the negative impact of minimum wage legislation on employment without lowering wages earned by employees. The subsidy increased dramatically in October 1995 and September 1996 (hereafter, PTE (payroll tax exemptions)). We have no information on the average payroll tax by wage. We then consider the following calibration. First, the payroll tax rate is the same for all jobs (abstract, routine, and manual) until the beginning of PTE and is identified using data in Figure 3. Second, at the beginning of PTE, payroll tax for abstract jobs is first fixed, then it adjusts in the same proportion as that described by Figure 3. Third, for routine and manual jobs, at the beginning of PTE, payroll tax falls linearly by 50% (it reaches a 50% decline at the end of the tax exemptions, which is consistent with the actual French reform). It then adjusts in the same

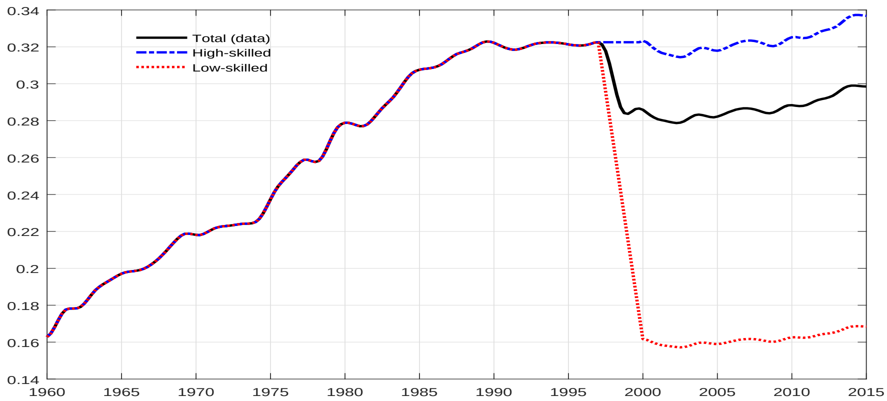
[12] In the literature, historical averages are considered to provide a proxy for the model steady state. Calibration then involves matching *one* empirical target. In our model, as we want to capture the technological *transition*, we need to set parameter values that allow to match as empirical targets *at each point in time*.

Figure 3: Labor market institutions I.: *Replacement rate, worker bargaining power, employers' and employees' social security contribution rates*



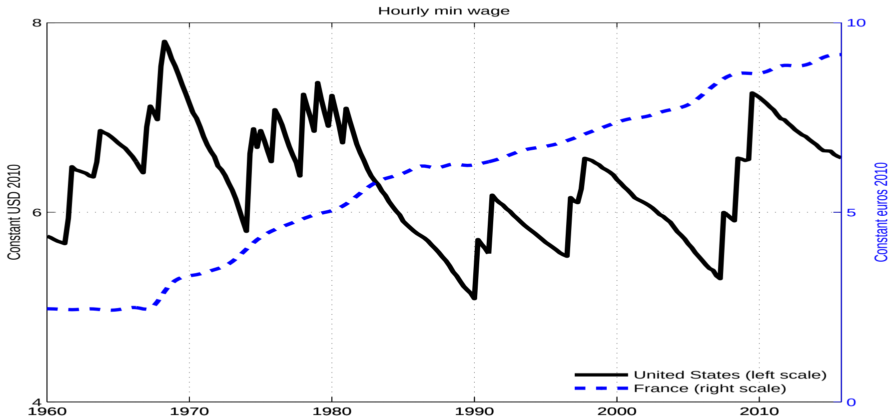
"Replacement rate" is the unemployment benefits replacement rate; "bargaining power" is workers' bargaining power; "employer SSC" is employer social security contribution; and "worker SSC" is worker social security contribution. See Appendix E for data sources.

Figure 4: Labor market institutions II. *French payroll tax adjusted for tax exemptions*



proportion as the one reported in Figure 3. Figure 4 displays the calibrated payroll tax.[13]

Figure 5: Labor market institutions III. *The minimum wage*



See Appendix E for details.

Finally, Figure 5 shows that the two countries experienced very different patterns of changes in minimum wage (MW) over the period: in France, we observe a continuous increase, whereas in the United States, it remains stable. It is important to note that the rise of the MW in France began in the late 1960s, before the beginning of the fall in the price of capital.

4.2 Calibration results

Calibration is quarterly. Preferences and technology parameters as well as the fall in the price of ICT p_K are assumed to be common to all countries. The scale parameters of the matching function, exogenous separation rates, are country-specific, as well as the shift in the labor supply of abstract workers. The total number of parameters is then 42. We consider 18 empirical targets:

$$\Psi_T = \left\{ \begin{array}{l} N_{a,i}(0), N_{r,i}(0), N_{m,i}(0), N_{a,i}(T), N_{r,i}(T), N_{m,i}(T), \\ E_i[N_a], E_i[N_r], E_i[N_m] \end{array} \right\}_{i=US,F} \quad \text{with } dim(\Psi_T) = 18,$$

where N refers to employment level, subscript i denotes the country (US or France), subscript and a, r, m denotes task (abstract, routine, manual). $(0, T)$ refers to the beginning (0) or the end (T) of the sample, $N_{a,i}(0)$ then denotes the abstract employment level in country i at the beginning of the sample. $E_i[N]$ refers to average employment over the whole sample.

In order to identify the unknown parameters, we introduce 24 restrictions. 19 restrictions are

[13] We make this simplifying assumption in order the keep the model tractable. PTE actually applies only to wages that lie below 1.33 times the minimum wage. In our simple calibration, PTE also applies to wages that lie above the upper bound of 1.33 minimum wage. These wages are earned by the most productive routine workers. We argue that this approximation has little consequence for our results, because PTE, by lowering labor costs, also tends to preserve routine jobs at the bottom of the productivity distribution. see Cheron et al. (2008) for an evaluation of this specific reform.

based on external information and five come from the following assumptions: *(i)* the efficiency of the labor market of high-skill workers is the same across countries, *(ii)* the path of technological progress is identical across countries, and normalized to unity at the initial period.[14] Hence, the model is just-identified.[15]

Exogenous variables are constrained by the following process:

$$x(t) = \begin{cases} x(0) & \text{if } \ t < t_{x0} \\ x(T) + (x(0) - x(T)) \exp(-\vartheta_x (t - t_{x0})^2) & \text{Otherwise,} \end{cases} \tag{23}$$

for $x = p_k, L_a$, in US or in France. T is the length of the sample. $x(0)$ and $x(T)$, for $x = p_k, L_a$ are the initial and terminal values. ϑ_x, for $x = p_k, L_a$, corresponds to the speed at which the variable adjusts to its final value. t_{x0} is the date at which the variable starts evolving. For the estimation, we assume that changes in the price of capital and in the education process begin respectively in $t_{k0} = 1975$ and $t_{L_a0} = 1960$ in the United States, whereas for France we set $t_{k0} = 1975$ and $t_{L_a0} = 1970$.[16] Our heterogeneous-agent model is non-stationary and non-linear, which requires an innovative solution method.[17] Table 1 summarizes the solution for 18 unknown parameters allowing us to minimize the distance between the targets and their theoretical counterparts.

Table 1: Parameter values

Preferences	ρ					
	0.65					
Learning	δ	λ				
	0.425	0.025				
Technology	A	A_s	σ	α	$\underline{\eta}$	$\overline{\eta}$
	3.5	0.3	0.74	0.3	0.48	1.44
Labor market	Υ_a	$\Upsilon_{r,US}$	$\Upsilon_{r,F}$	$\Upsilon_{m,US}$	$\Upsilon_{m,F}$	
	0.11	0.09	0.129	0.067	0.045	
Structural changes	ϑ_{pk}	$p_k(T)$	$\vartheta_{La,US}$	$\vartheta_{La,F}$		
	0.00025	0.475	0.00007	0.00005		

We check that the model provides a good fit of the data (Appendix F.2). Note that the elasticity of substitution in production between capital and routine workers ($\frac{1}{1-\sigma}$) is larger than the elasticity of substitution in consumption between goods and services ($\frac{1}{1-\rho}$). As stressed by

[14]This restriction does not mean that the level of the technology is the same on both side of the Atlantic: the endogenous level of capital in ICT controls for heterogeneous initial endowments between France and the United (more than twice as large in the United States).

[15]See Appendix F.1 for a detailed description of calibration. We do not report standard deviations around parameter values as, for the sake of simplicity, the uncertainty on some empirical targets were not taken into account: our model's simulated *paths* must match empirical targets that are representative of employment paths (employment at beginning and end of technological changes, as well as average employment). If we were to take into account uncertainty around the empirical targets, we would have taken into account uncertainty *only* on the average values $E_i[N]$, which are moments. Other empirical targets are not uncertain because they relate to observed values $N(0$ and $N(T)$. These empirical targets are not moments, so, they are not uncertain.

[16]These starting date are chosen because they correspond to the product launch of the first IBM personal computer, and the take-off of the number of students in universities. Justiano et al. (2010) and Karabarbounis & Neiman (2014) also report a sharp decline in the price of investment goods, starting in 1975.

[17]The algorithm is presented in Appendix G.

Autor & Dorn (2013), this ensures that the polarization process actually occurs: falling price of capital cause routine workers to be replaced by capital. Low-skill labor flows from routine to manual jobs, all the more so as consumption complementarity ensures that demand for manual tasks increases, along with the demand for goods. In addition, the learning process appears slow ($\lambda = 0.025$ means that it takes 10 years to become an experienced manual worker) and the productivity gap between experienced and novice manual workers is large ($\delta = 0.425$). The mobility cost might seem large compared to the empirical estimates in Cortes (2015). However, note that the reference worker in our model is the experienced manual worker, while Cortes (2015) compare the fate of routine switchers (who changed occupations) to routine stayers (who remained in the routine employment pool). Our calibration suggests that the average manual worker in the model has 10 years of work experience. As such, the experienced manual worker is more than twice as productive as a novice manual worker ($\delta = 0.425$).

5 Accounting for polarization across countries

In this section, we perform counterfactual exercises to disentangle the role of each exogenous trend (TBTC, LMI or educational attainment) in accounting for the job polarisation process. Using our model, we predict employment changes when one of the exogenous trends is set at a constant level (its 1975 value, instead of evolving as described in section 4).

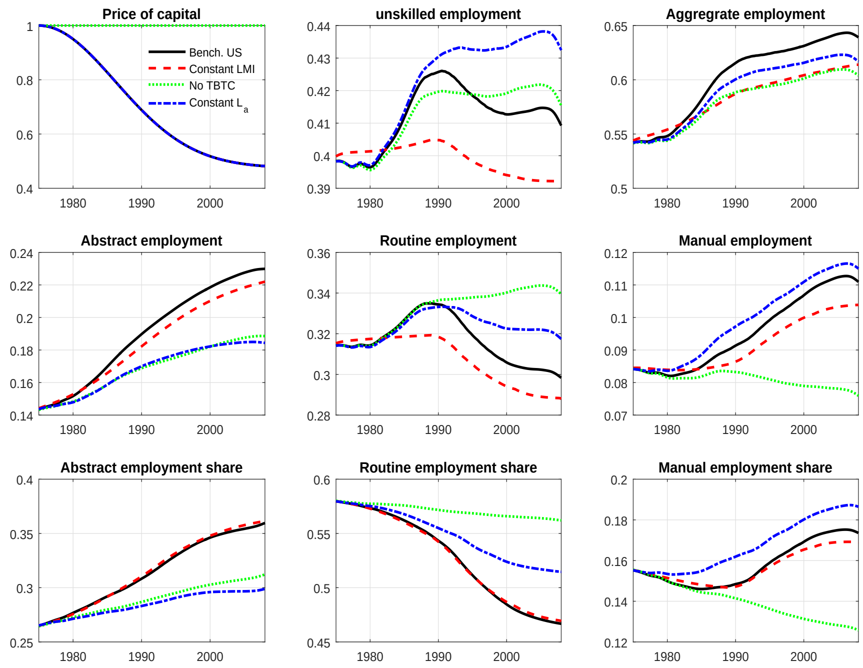
5.1 TBTC

The relevance of Autor & Dorn (2013)'s story to account for US polarization. In Autor & Dorn (2013), TBTC is the only phenomenon that potentially explains all the qualitative dimensions of polarization. The decline in the price of capital reduces the marginal productivity of routine task. Part of this lost competitiveness is absorbed by a fall in the routine wage. The total effect is a decline in tightness and wages for these workers. On the other hand, TBTC increases productivity of abstract tasks, thanks to the expansion of capital stock. Despite an offsetting effect induced by a higher wage in abstract jobs, the total effect is an increase in tightness and wages for abstract workers. Taking into account the expansion in demand and the endogenous rise in the relative price of service, this supply shock also generates additional incomes. Demand for goods and services increase, as consumers favor variety over specialization. Given that the good market is also affected by the positive supply shock, the increase in the price of services is necessarily larger than that observed in the goods market. The relative price of services therefore increases, and so does the marginal gains of services produced by manual workers. The feedback effect on the labor market magnifies the initial impact of the supply shock. Indeed, the marginal return of services goes up, and hence so do wages in the service sector: this higher return of manual jobs entices more routine workers to move towards manual jobs.

The benchmark results on the US economy are consistent with Autor & Dorn (2013)'s economic mechanisms (Figure 6). [18] To illustrate the leading role of TBTC in the process, we display in

[18] The dynamics of productivities, wages, and job finding rates are displayed in Appendix H, with Figures 22

Figure 6: Employment levels and shares *US economy*



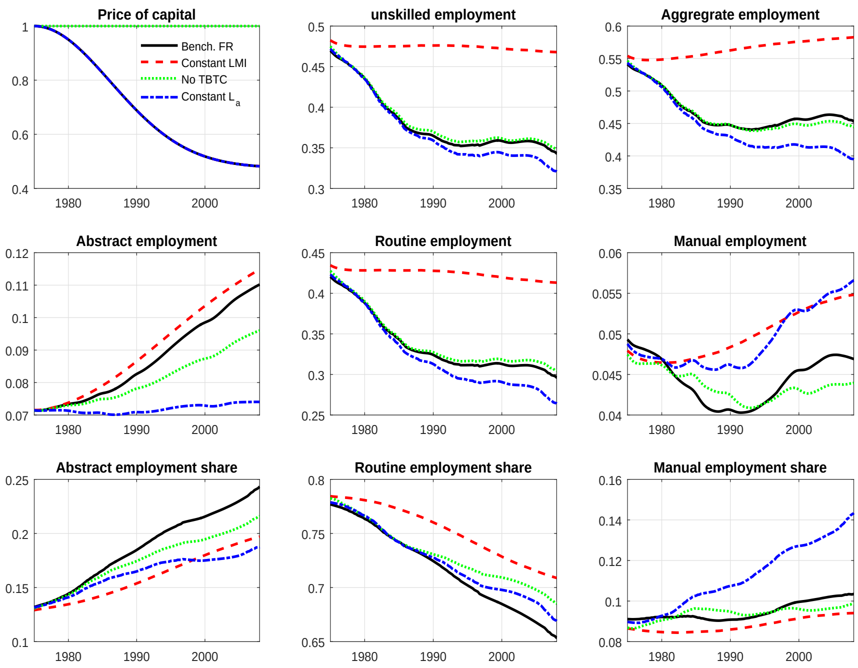
“Bench US” Benchmark calibration: TBTC, rising L_a and LMI shifts. “Constant LMI” Economy with constant LMI, set at 1975 level. “No TBTC” Economy with constant price of capital, set at 1975 level. “Constant L_a” Economy with constant supply of skilled labor, set at 1975 level.

Figure 6 the predicted employment paths when we shut down the fall in the computer price. Without TBTC, the US labor market does not polarize: routine employment does not fall, manual employment does not expand, while abstract employment growth is limited. The rise in aggregate employment is 4 pp lower than the benchmark in 2007. This means that, without TBTC, US employment gains would have been 40% lower (4 pp divided by 10 pp employment gain between early 1980s and 2007 in the benchmark calibration).

TBTC: Little impact on employment in France. In contrast, in France, TBTC has no significant impact on aggregate employment (Figure 7). With respect to the United States, the impact of TBTC on routine and manual unskilled workers is limited, leading to moderate reallocation flows. It is especially the case for routine jobs that have been the decisive factor in the drop in jobs in France until at least the mid-1990s (Appendix B). This apparently limited impact of TBTC on French employment does not imply that technological changes did not affect French employment. We argue below that changes in LMI actually overcame the impact of TBTC in France.

and 23 for the US and French economies, respectively.

Figure 7: Employment levels and shares. *French economy*



"Bench FR" Benchmark calibration: TBTC, rising L_a and LMI shifts. "Constant LMI" Economy with constant LMI, set at 1975 level. "No TBTC" Economy with constant price of capital, set at 1975 level. "Constant L_a" Economy with constant supply of skilled labor, set at 1975 level.

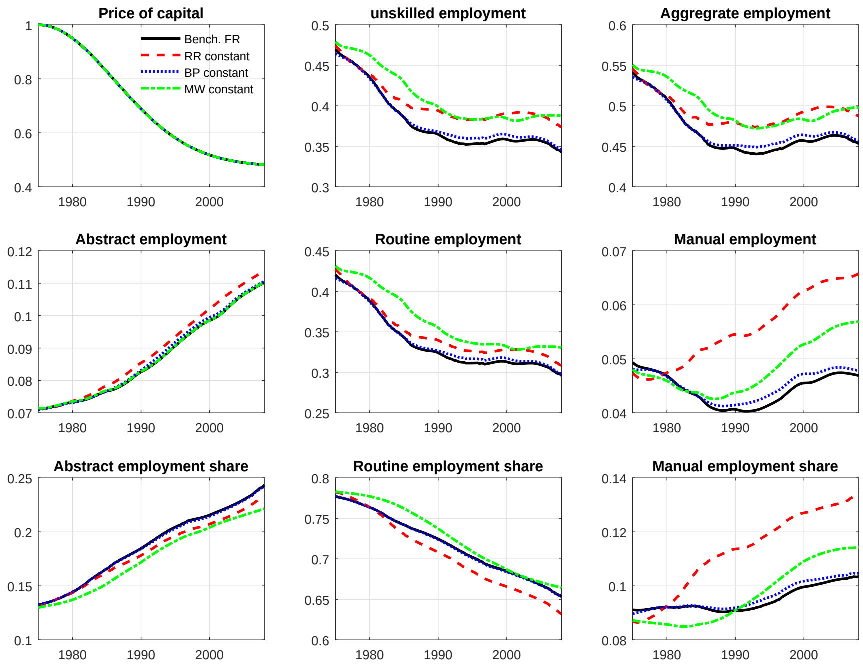
5.2 Rising educational attainment: Important element in the polarization process, more so in France than in the United States

First, the effect of rising educational attainment on abstract workers is straightforward: without the boom in the supply of skilled labor, the expansion in abstract jobs would have been more limited, in both countries (Figures 6 and 7). Second, the effect of rising educational attainment on unskilled workers is more subtle. *(i)* On the one hand, by definition, when the number of skilled workers increases, the number of unskilled worker declines because we normalize the population to one. Owing to this accounting mechanism, the rising supply of skilled labor lowers manual and routine employment. *(ii)* On the other hand, rising educational attainment fosters low-skill employment: rising employment of abstract workers in the factory boosts routine productivity and fuels the demand for services provided by manual workers. Given our benchmark calibration, the first mechanism *(i)* is predominant: without the rising educational attainment, there would have been more unskilled workers. For French routine workers, *(ii)* actually prevails.

Without the rise in educational attainment, aggregate employment declines with respect to the benchmark scenario. In the United States, the gap between the benchmark and the counterfactual amounts to 2.5 percentage points in 2007, which suggests that, absent the rise in the supply of skilled labor, the US employment growth would have been approximately 25% lower (2.5 pp divided by the 10pp rise in aggregate employment between 1975 and 2007; see Figure

6). In France, the model predicts that, without the increase in skilled labor, the fall in employment would have been 50% higher (5 pp gap between the benchmark and the counterfactual in 2007 divided by the 10 pp fall from 1975 to 2007; see Figure 7). Overall, the increase in skilled labor supply has benefited total employment through a composition effect because it is the most profitable type of job. This is particularly true in France, where the job value of skilled workers relative to that of unskilled workers is especially high.

Figure 8: Employment levels and share: A decomposition of the LMI changes. *French economy*



“Bench FR” Benchmark calibration: TBTC, rising L_a, and LMI shifts; “RR Constant” Economy with constant RR, set at 1975 level; “BP Constant” Economy with constant bargaining power, set at 1975 level; “MW Constant” Economy with constant supply of minimum wage, set at 1975 level.

5.3 LMI

France: rising minimum wage and replacement ratio until the mid-1990s and payroll tax cuts after 1995 stalled job polarization. In France, LMI lowered employment, reducing the overall profitability of employment (Figure 7). Moreover, the impact of LMI is quite different according to the type of job, and accounts for the much more pronounced disappearance of routine jobs in France. In a context of reduced demand for labor and downward pressure on wages to limit the decline in their profitability, the sizeable rise in the MW has eliminated many routine jobs in France (see Figure 8 for a decomposition of the LMI in France). This is much more brutal than the pace impelled in the United States. What was considered the influence of TBTC in the literature was in fact the impact of LMI, and in particular, the increase in the MW. LMI also curbed the rise in demand for abstract and manual jobs, which explains the overall context of declining employment levels in France. Bargaining power explains little of the employment dynamics in France, while the opposite is true in the United States (Figures 8 and 9). On the other hand, increases in MW and the replacement ratio have significantly changed the dynamics of employment over the past 30 years in France. They both explain the decline in aggregate employment. Note that their influence is modest on the employment of abstract jobs, which is expected. In contrast, routine jobs are particularly affected by the increase in the MW, while manual jobs would have increased considerably if the replacement ratio had remained constant.

This French polarization occurs until the mid-1990s. Since then, and until the end of the sample, the drop in the level of routine jobs stops, and aggregate employment starts to rise again. Figure 10 shows that this is due to the policy of subsidies for low paid jobs, which have made it possible to limit the effects of the MW on the labor cost. This subsidy policy has actually helped support unskilled employment in France, which would otherwise have continued to suffer from the rising MW.

De-unionization stimulates US job opportunities created by TBTC. In the US economy (Figure 6), LMI increased employment, whereas LMI lowered employment in France until the mid-1990s. LMI in the United States seem to contribute as much as TBTC in explaining the rise in aggregate employment. Despite LMI having a positive impact on routine employment, the routine share is the same as in the benchmark. Why? Figure 9 decomposes the role of the LMI. The fall in the bargaining power seems to drive the results: The "BP constant" scenario involves lower employment in all occupations compared to the benchmark case. With all employment levels declining, the shares remain virtually unchanged. The MW ("MW constant") and the replacement rate ("RR constant") scenarios both seem to raise routine employment, as they make the routine jobs more attractive. These two scenarios produce small changes with respect to the benchmark case, as the effects of changes in bargaining power appear quantitatively predominant.

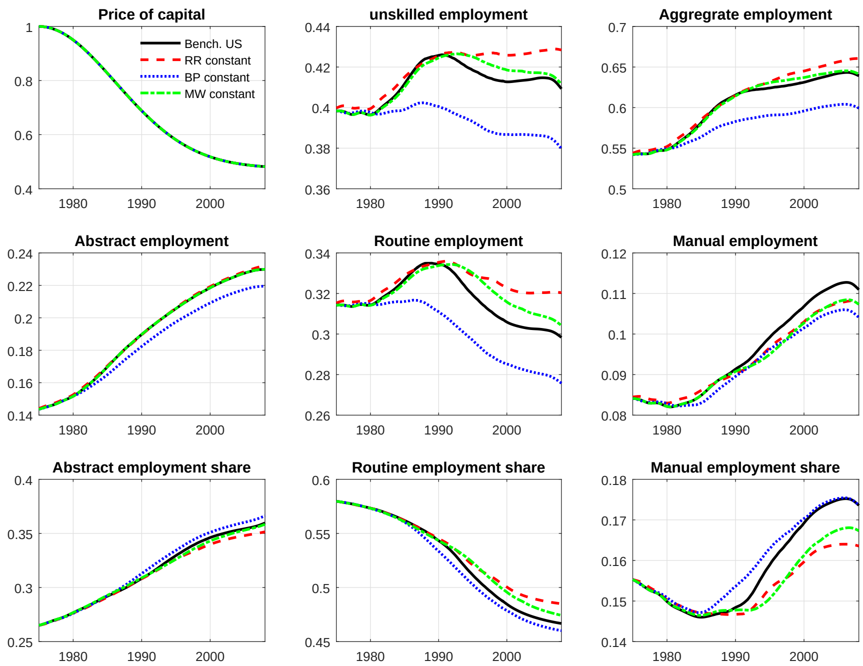
6 Winners and losers of the US and French polarization

> *"What is happening in the American political system? How has a country that has benefited-perhaps more than any other-from [..] technological innovation suddenly developed a strain of [..] anti-innovation protectionism? Why have some on the far left and even more on the far right embraced a crude populism?"*, B. Obama, The Economist, October 2016.

We have focused so far on employment. LMI changes in the United States has favored the creation of new job opportunities driven by TBTC, whereas in France, opposite LMI changes led to evict these new job opportunities. Nevertheless, recent political events entices us to go beyond the analysis of employment gains or losses.

We turn to the welfare implications of TBTC. The main interest of welfare measures (captured by value functions) is to account for changes in earnings and employment opportunities, from an inter-temporal perspective: even if new technologies create new job opportunities, it is

Figure 9: Employment levels and share: A decomposition of the LMI changes. *US economy*



"Bench US" Benchmark calibration: TBTC, rising L_a and LMI shifts; "RR Constant" Economy with constant RR, set at 1975 level; "BP Constant" Economy with constant bargaining power, set at 1975 level; "MW Constant" Economy with constant supply of MW, set at 1975 level.

important to evaluate whether the sharing rule of these new surpluses has not shifted in disfavor of workers (whether employed or unemployed), thereby reducing worker's perceived value of this structural change. Given the absence of financial markets in our analysis, we focus on workers' welfare, omitting then the profits generated for shareholders as well as the public debt. As we have heterogeneous workers across tasks and within tasks, our analysis allows to identify the winners and losers of the technological and institutional shifts.[19] We first look at the common welfare results in France and in the United States (Section 6.1) before stressing the differences (Section 6.2). [20]

[19]We also use average value functions, $\overline{W}$, $\overline{U}$ and $\overline{\Omega}$, for each worker group, defined as follows:

$$\overline{W}_{\text{routine}} = \frac{\sum_{\eta\geq\tilde{\eta}} N_r(\eta)\mathcal{W}_r(\eta)}{\sum_{\eta\geq\tilde{\eta}} N_r(\eta)} \qquad \overline{U}_{\text{routine}} = \frac{\sum_{\eta\geq\tilde{\eta}} U_r(\eta)\mathcal{U}_r(\eta)}{\sum_{\eta\geq\tilde{\eta}} U_r(\eta)} \qquad \overline{\Omega}_{\text{routine}} = \frac{\sum_{\eta\geq\tilde{\eta}}[N_r(\eta)\mathcal{W}_r(\eta)+U_r(\eta)\mathcal{U}_r(\eta)]}{\sum_{\eta\geq\tilde{\eta}}[N_r(\eta)+U_r(\eta)]}$$

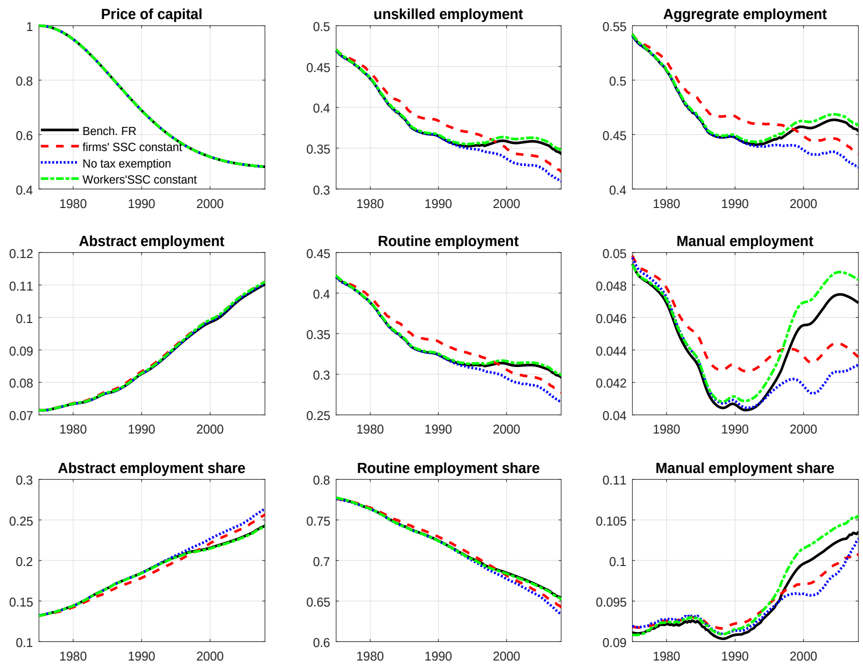
$$\overline{W}_{\text{manual}} = \frac{N_s\mathcal{W}_s+N_m^o\mathcal{W}_m^o+\sum_{\eta<\tilde{\eta}} N_m^n(\eta)\mathcal{W}_m^n(\eta)}{N_s+N_m^o+\sum_{\eta<\tilde{\eta}} N_m^n(\eta)} \qquad \overline{U}_{\text{manual}} = \frac{U_s\mathcal{U}_s+U_m^o\mathcal{U}_m^o+\sum_{\eta<\tilde{\eta}} U_m^n(\eta)\mathcal{U}_m^n(\eta)}{U_s+U_m^o+\sum_{\eta<\tilde{\eta}} U_m^n(\eta)}$$

$$\overline{\Omega}_{\text{manual}} = \frac{N_s\mathcal{W}_s + N_m^o\mathcal{W}_m^o + U_s\mathcal{U}_s + U_m^o\mathcal{U}_m^o + \sum_{\eta<\tilde{\eta}}[N_m^n(\eta)\mathcal{W}_m^n(\eta) + U_m^n(\eta)\mathcal{U}_m^n(\eta)]}{N_s + N_m^o + U_s + U_m^o + \sum_{\eta<\tilde{\eta}}[N_m^n(\eta) + U_m^n(\eta)]}$$

and $\overline{\Omega}$ abstract $= \frac{N_a\mathcal{W}_a+U_a\mathcal{U}_a}{N_a+U_a}$. All welfare measures $\overline{W}, \overline{U}, \overline{\Omega}$ are then divided by the consumer price index. They therefore take into account the increase in consumer price index due to the gradual rise in the relative price of service.

[20]In Appendix D.4, we discuss the caveats of our model for the welfare analysis.

Figure 10: The role of subsidies for low-paid jobs *French economy*



"Bench FR" Benchmark calibration: TBTC, rising L_a and LMI shifts; "firms' SSC Constant" Economy with constant τ^f, set at 1975 level; "No tax exemption" Economy with a homogenous tax rate τ^f even after 1996; "Workers' SSC Constant" Economy with constant τ^w, set at 1975 level.

6.1 Common welfare results

Average welfare increased in both countries. Figures 11 and 12 report the evolution of value functions. Abstract and manual workers enjoy a significant increase in welfare: in both countries, these workers benefited from job polarization. The evolution of routine welfare differs across countries (see Section 6.2). Let us stress that, in both countries, in the routine group, low-ability workers (with gloomy employment prospects) gradually switch to manual jobs. As more and more low-ability routine workers leave the routine pool, average welfare in the routine group still rises in both countries. As a result, Obama's intuition on the benefits of job polarization is relevant in the United States, as well as in France, when we look at the evolution of average welfare. However, dealing with average values only tells us one side of the story, as it hides individual heterogeneity. Indeed, there are strong selection effects which drive the evolution of individual welfare. They are crucial to identify the winners and losers of structural changes.

Manual and abstract workers are the winners of TBTC. In both countries, the gains from polarization are not equally shared. Figure 13 reports workers' welfare across task groups when we perform our counterfactual experiments.[21]

[21] We compute the gaps between the expected welfare of the benchmark economy and the counterfactual scenario.

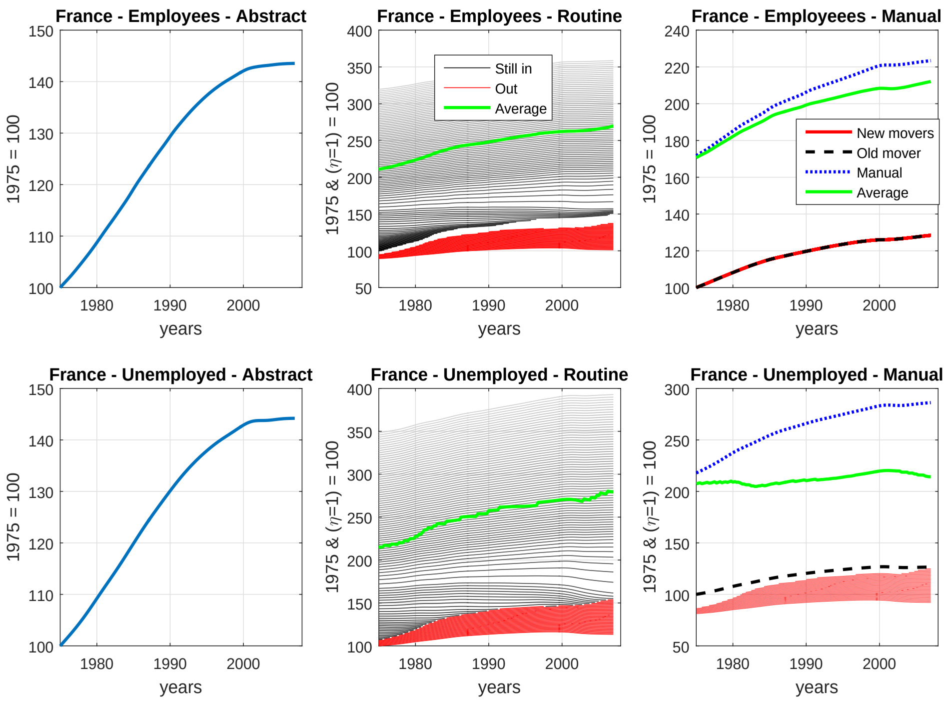
Figure 11: Workers' welfare changes in the United States

All welfare measures are indices, Index base 100 = 1975. For routine jobs, Index base 100 = 1975 for $\widetilde{\eta}$, and Index base $100 * \text{Welfare}(\eta)/\text{Welfare}(\widetilde{\eta}) = 1975$ for $\eta > \widetilde{\eta}$. This means that, in 1975, the highest ability employee on a routine job had a welfare 3.5 times larger than the lowest ability employee. Idem for the "Average."
For Routine workers, "Still in routine": employed as routine worker, the highest welfare line is the routine worker with the highest productivity η, "No longer in routine": displaced routine worker (with the lowest productivity η) who switch to manual job.

If TBTC had not happened, abstract and manual workers would have been worse off in both countries. As expected, these workers are the main winners of the technological transition. Indeed, abstract workers benefit from a sizeable increase in productivity. They benefit from the rising labor demand for abstract tasks. As abstract workers need more services provided by manual workers, this task group benefits from improved employment prospects. Welfare gains are smaller in France than in the United States because LMI changes tend to dampen the expansion in employment opportunities. However, the two countries share the same qualitative feature: manual and abstract workers are the winners of TBTC, with larger welfare gains for the latter. The impact of TBTC on routine workers is ambiguous. Some gain, others lose (Figures 11 and 12), but in both cases, the effects remain rather low. Note that it is the workers with the lowest productivity who benefit from the gains of technical progress in a rather similar way in the two countries.

Manual and routine workers benefit from rising educational attainment. The rise in the share of skilled workers has been welfare improving for routine and manual workers. In Figures 13, 14 and 15, routine and manual workers would have been worse off if educational attainment had not expanded. Indeed, routine workers' productivity improves thanks to the

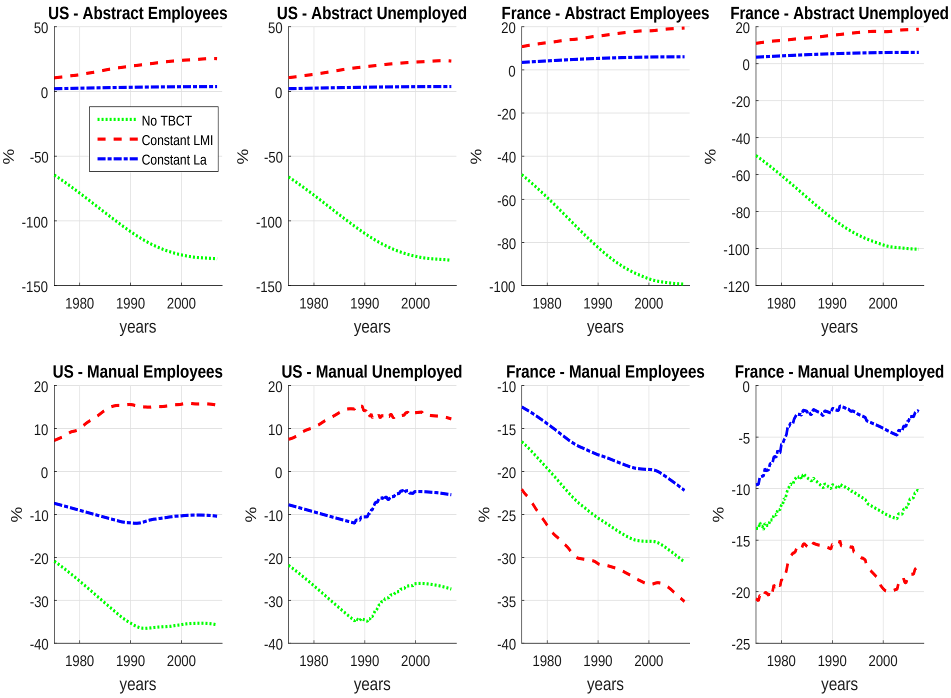
Figure 12: Workers' welfare changes in France



All welfare measures are indices, with an index base 100 = 1975. For routine jobs, the index base 100 = 1975 for $\widetilde{\eta}$, and the index base is $100 * \text{Welfare}(\eta)/\text{Welfare}(\widetilde{\eta}) = 1975$ for $\eta > \widetilde{\eta}$. This means that, in 1975, the highest ability employee on a routine job had a welfare 3.2 times larger than the lowest ability employee. Similarly for the "Average."

For Routine workers, "Still in routine": employed as routine worker, the highest welfare line is the routine worker with the highest productivity η, "No longer in routine": displaced routine worker (with the lowest productivity η) who switch to manual job.

Figure 13: Abstract and manual workers' welfare changes: Counterfactuals



"%": welfare gap (in percentage) between benchmark simulation and counterfactual experiment. "Constant LMI": LMI set at 1975 value. "No TBTC": price of capital p_k is constant. "Constant L_a": L_a constant, set at 1975 value.

rise in skilled employment. Manual workers' improved employment prospects are fostered by the rising demand for services from skilled workers. The rise in the supply of educated workers reduces the average welfare of abstract workers, who are constrained to share the new employment surpluses among a larger number of persons.[22]

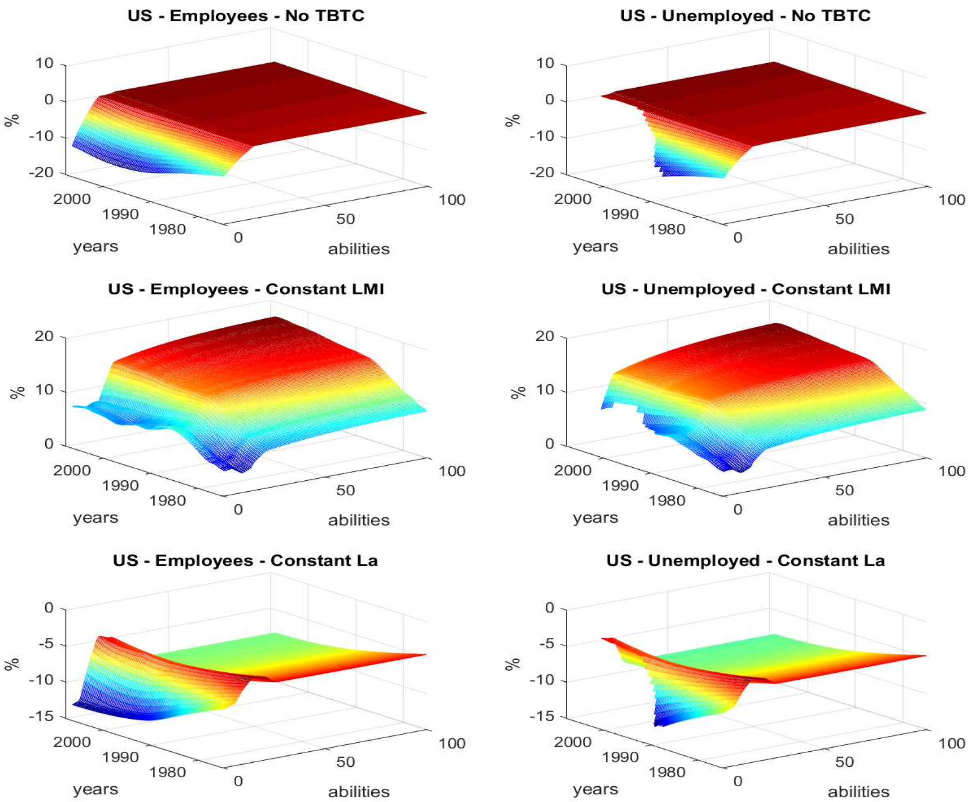
6.2 Divergent welfare outcomes: the fate of unskilled workers linked to LMI changes

The welfare measure takes into account two elements that evolve in opposite directions. The first element relates to employment opportunities. In section 5, we commented the impact of LMI on workers' employment and showed how changes in LMI drove French employment downwards, while US employment growth was fostered by de-unionization. The second element relates to changes in earnings that have also been affected by LMI (minimum wage and worker's bargaining power when employed, unemployment benefits when unemployed). LMI changes in France reduced employment opportunities, but also increased social insurance and workers'

[22]The reader might be surprised that the economic mechanisms are different from the ones mentioned in section 5. Recall that we analyze here the average individual welfare so that productivity and wages matter. In contrast, in section 5, we considered the sum of employment over the total number of workers, such that the mass of skilled and unskilled workers matters.

share of employment surplus, and vice versa in the United States.

Figure 14: Routine workers' welfare variations in the United States: Counterfactuals



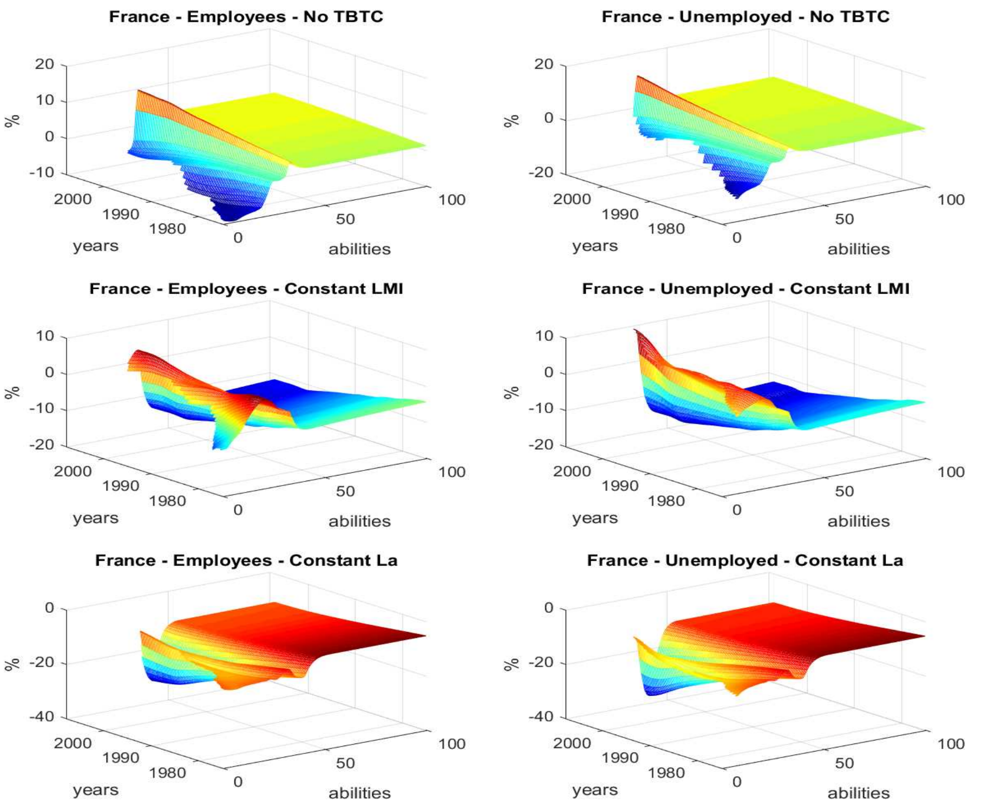
"%": welfare gap (in percentage) between benchmark simulation and counterfactual experiment; "Constant LMI": LMI set at 1975 value; "No TBTC": price of capital p_k is constant; "Constant L_a": L_a set at 1975 value;

In the United States Figure 14 suggests that changes in social insurance and workers' share of employment surplus[23] are the main drivers for welfare results on unskilled workers. With constant LMI (the United States keep the "generous" LMI of the 1970s), routine and manual workers in the United States are better off than in the benchmark economy (a gradual transition towards a more "flexible" economy). This welfare reduction due to LMI explains why the welfare of routine job workers is declining over these two decades (1975–1995), as shown in Figure 11. This suggests that US unskilled workers have suffered since the early 1980s from a decline in their market power and a fall in redistributive policies. Within the pool of the routine workers, stayers (high ability η) prefer more generous share of employment surplus (larger workers' bargaining power), while switchers (low ability η) prefer more generous replacement ratios. These institutional drifts may partly explain why a fraction of American workers does not support technological changes: they do not receive a sufficient share of the

[23]We have shown in Figure 9 that workers' bargaining power (BP) is the main explaining factors for the impact of LMI in the United States.

associated surplus and they lose too much income during the reallocation process.

Figure 15: Routine workers' welfare variations in France: Counterfactuals



"%": welfare gap (in percentage) between benchmark simulation and counterfactual experiment; "Constant LMI": LMI set at 1975 value; "No TBTC": price of capital p_k is constant; "Constant L_a": L_a set at 1975 value.

In France Figure 15 shows that with constant LMI[24] (France remains under the "flexible" labor market of the 1970s), French routine workers are worse off than in the benchmark economy (a gradual transition towards a more "rigid" economy), except some routine workers with the lowest ability. This means that the employment effect dominates the income effect only for these low ability workers in France. Stayers (insiders), who did not switch occupation, prefer to receive a large share of the surplus. They are the high-ability routine workers. They are barely affected by changes in the replacement ratio (as they are mostly employed workers) and are away from the MW. Conversely, movers (outsiders), who need to find a job in another occupation, are low-ability routine displaced workers. They are concerned about employment prospects and unemployment benefits while looking for a new job. These are low-ability routine displaced workers. These workers in France are worse off with constant LMI, and they are the primary losers of LMI drifts. Hence, inside the pool of the routine workers, stayers (high ability

[24]In France, the main factors explaining the impact of the LMI are the minimum wage (MW) and the replacement rate (RR) until the mid-1990s, and payroll tax cuts after 1995. See Figure 8.

η) prefer more generous LMI while switchers (low ability η) prefer flexible LMI.

7 Conclusion

We first shed light on job polarization using US and French data. Dynamics of employment *shares* for abstract, routine, and manual jobs appear very similar across countries. This similarity actually hides major differences in the dynamics of employment *levels* by tasks. In particular, routine employment level actually fell in France until the mid-1990s, then rebounded until 2007. The evolution of US routine employment went in opposite directions to that of the French economy. We develop a multi-sectorial search and matching model with endogenous occupational choice to shed light on the impact of task biased technological change, labor market institutions, and rising educational attainment on job polarization. For the US economy, we find that TBTC and the rising supply of skilled labor are the main drivers of polarization in a context of growing employment levels. In France, polarization is driven mainly by LMI changes, leading to a sharp drop in routine employment in a context of declining aggregate employment until the mid-1990s, and then a reverse dynamic when the impact of the MW has been alleviated by a subsidy policy targeted at low-wage earners. We then quantify the welfare consequences of job polarization. Abstract and manual workers are the main winners of job polarization in both countries. Welfare gains and losses contrast more in the routine group across France and in the United States. American routine workers have seen their welfare falling, owing to the reduction in LMI generosity. What is generally considered the result of TBTC is actually the result of the LMI dynamics. Symmetrically, the increase in the generosity of LMI in France has improved the well-being of routine workers, at least for those who did not lose their jobs.

Our analysis reveals the different nature of the polarization that seems to have affected the United States and France in a common way. The similar evolution of job shares hides different evolutions of the LMI, which have produced opposite consequences on employment and welfare levels. France has chosen to support the fate of routine workers, unlike the United States. This costly choice in terms of employment at the macroeconomic level has allowed the French middle class to benefit from the gains associated with TBTC.

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A Annual data on employment by task

A.1 US data

As in Jaimovich & Siu (2012), we consider only individuals aged 16 and more. Occupations in farming, fishing, forestry, and military are excluded. Occupations are categorized into three groups, each corresponding to the main tasks performed on the job. In doing so, we follow Jaimovich & Siu (2012). Beginning in 1983, the classification is based on the categorization of occupations in the 2000 Standard Occupational Classification system. Employment data from January 1983 onwards are taken from FRED. Non-routine cognitive workers are those employed in "management, business, and financial operations occupations" and "professional and related occupations." Routine workers are those in "sales and related occupations," "office and administrative support occupations," "production occupations," "transportation and material moving occupations," "construction and extraction occupations," and "installation, maintenance, and repair occupations." Non-routine manual occupations are "service occupations." We checked that employment stocks by task are similar to Figure 4 in Jaimovich & Siu (2012).

A.2 French data

We repeat the US procedure on French data in order to ensure comparability across countries. We use the LFS from 1983 through 2007. The survey was redesigned in 2003. Prior to 2003, the survey was annual. Individuals were surveyed each year, for three years in a row. Since 2003, the survey is quarterly. Each individual is surveyed every quarter, for six quarters in a row. The survey is designed to be representative of the French population, with more than 130,000 observations in year 1983 and approximately 70,000 each quarter for year 2007. As in Jaimovich & Siu (2012), we consider only individuals aged 16 and more.

As for occupations, we apply the procedure used for US data. Occupations in farming, fishing, and forestry are excluded. Occupations are categorized into three groups, each corresponding to the main tasks performed on the job. We base our categorization on the two-digit occupational codes.[25] We want our assignment of occupations to tasks to match the one used in Jaimovich & Siu (2012).

Abstract jobs are management, business, science, and arts occupations; this includes occupation codes 23 large business heads, 31 licensed professionals, 33 civil servant, executives, 34 scientific professional, 35 creative professional, 37 top managers and professionals, 38 technical manager, engineers, 42 teacher, and 43 health workers. [26]

Routine jobs are sales and office occupations; construction and maintenance occupations, and production, transportation, and material moving occupations; this includes occupation codes 45 mid-level professionals in the public sector, office worker, 46 mid-level professionals in the corporate sector, office workers, 47 technician, 48 foremen, supervisors, 52 civil servants, office workers, mid-level and low level, 53 security workers, 54 office workers in the corporate sector, 55 retail worker, 62 skilled industrial workers, 63 skilled manual laborers, 64 drivers, 65 skilled distribution worker (dispatch, dockers, warehousemen, ...), 67 low skill workers, in manufacturing, food industries, press, ... 68 low skill laborers, craftsmen

Manual jobs are service occupations. This includes occupation codes 56 Personal service workers and 22 heads of small businesses (selling food, tobacco, services, and other items)

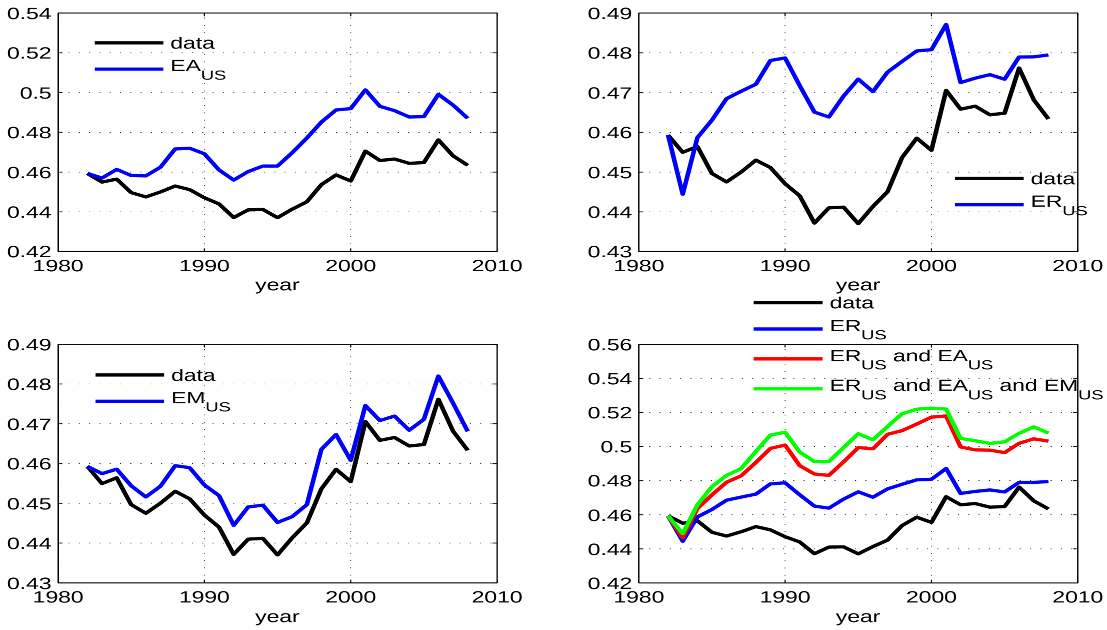
B Key role of routine employment in accounting for cross-country divergence in employment levels

The dynamics of routine employment explains the main difference in the evolution of employment levels in France and the United States. Figure 16 shows it explicitly, using counterfactual exercises. Each curve corresponds to the counterfactual French employment level that would have been observed in the employment growth has been that observed in the United States. Changes in the US employment of abstract and services do not significantly change the dynamics of the French employment compared to that observed. On the other hand, if France had experienced the US dynamics of routine employment, changes in the French aggregate employment would have been radically changed, and indeed quite constant over the whole period. We would have missed the sharp downturn in routine employment until the mid-1990s and then the upturn prior to the last recession.

[25] Harrigan et al. (2016) argue that two-digit codes used in French data are economically meaningful. Each code is the aggregation of 10 to 20 four-digit sub-occupations with stark differences in the susceptibility of jobs to automation.

[26] Some could argue that occupation 43 could also be considered to be part of manual non-routine jobs. We choose to consider them in the abstract group, as Charnoz & Orand (2015). These authors consider the same group of occupations in the abstract group and checked that these jobs are indeed characterized by abstract-intensive tasks. In addition, Jaimovich & Siu (2012) also consider medical occupations as part of non-routine cognitive jobs.

Figure 16: Counterfactual employment levels: France



"Data" French data; "EA_{US}": counterfactual French employment with US employment growth in abstract jobs; "ER_{US}": counterfactual French employment with US employment growth in routine jobs; "EM_{US}": counterfactual French employment with US employment growth in manual jobs.

C Graphical presentation of the model

Figure 17: Building blocks of the model

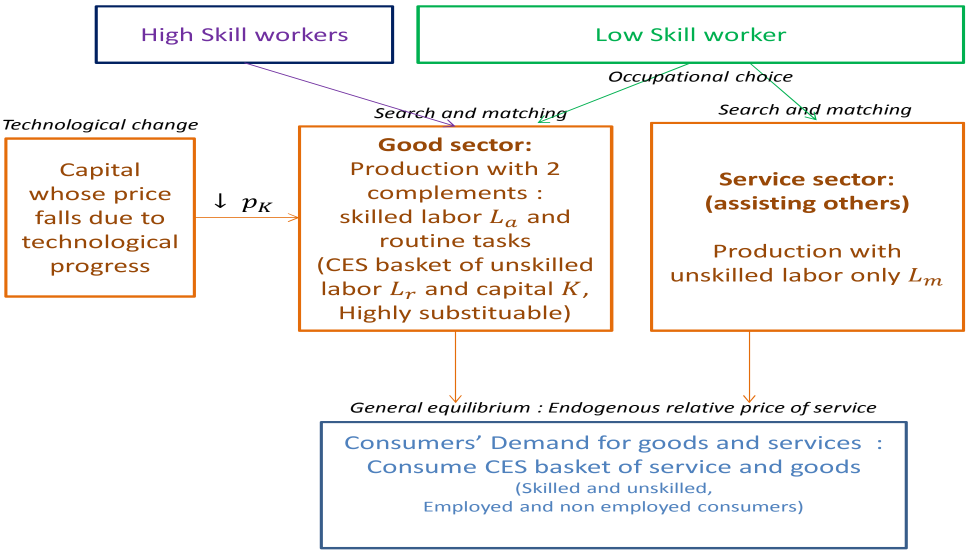


Figure 18: Heterogeneous workers

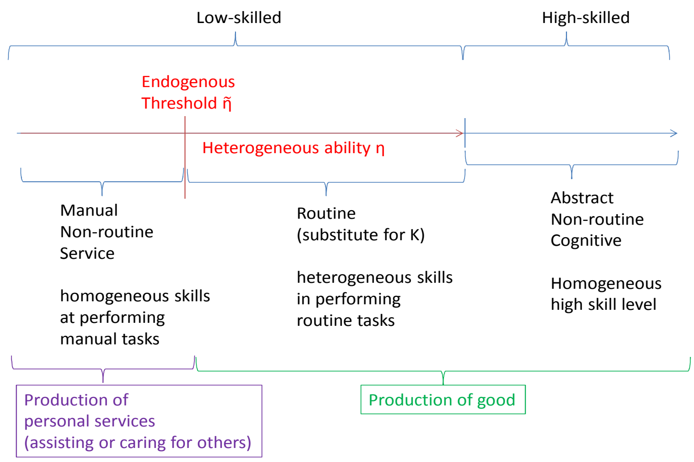
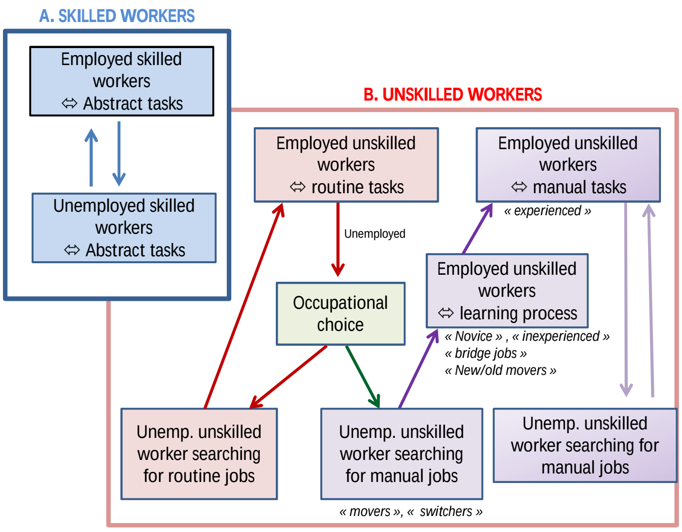


Figure 19: Worker flows



D Model

D.1 Job creation equations

Together with the firm present values of a filled job, we obtain the following job creation condition for skilled workers:

$$\frac{c_a}{q_a} = \beta\left[y_{a,+1} - (1+\tau^f_{h,+1})w_{a,+1} + (1-s_a)\frac{c_a}{q_{a,+1}}\right]$$

whereas, for unskilled workers, job creation conditions are:

$$\begin{aligned}
\frac{c}{q_r(\eta)} &= \beta\left[y_{r,+1}(\eta) - (1+\tau^f_{l,+1})w_{r,+1}(\eta) + (1-s_r)\frac{c}{q_{r,+1}(\eta)}\right]\\
\frac{c}{q^n_m(\eta)} &= \beta\left[p_{s,+1}\delta A_s - (1+\tau^f_{l,+1})w^n_{m,+1}(\eta) + (1-s_m)\left(\frac{c(1-\lambda)}{q^n_{m,+1}(\eta)} + \frac{c\lambda}{q_{m,+1}}\right)\right]\\
\frac{c}{q^o_m} &= \beta\left[p_{s,+1}\delta A_s - (1+\tau^f_{l,+1})w^o_{m,+1} + (1-s_m)\left(\frac{c(1-\lambda)}{q^o_{m,+1}} + \frac{c\lambda}{q_{m,+1}}\right)\right]\\
\frac{c}{q_m} &= \beta\left[p_{s,+1}A_s - (1+\tau^f_{l,+1})w_{m,+1} + (1-s_m)\frac{c}{q_{m,+1}}\right]
\end{aligned}$$

D.2 Wage equations

Abstract jobs:

$$w_a = \frac{\gamma}{1+\tau^f}\left(y_a + \Gamma(\tau^f_{+1},\tau^w_{+1})\frac{\phi_{+1}}{\phi}c_a\theta_a + (1-s_a)\frac{c_a}{q_a}\left(1-\frac{\phi_{+1}}{\phi}\Gamma(\tau^f_{+1},\tau^w_{+1})\right)\right) + \frac{1-\gamma}{1-\tau^w}z_a$$

where $\phi = \frac{\gamma}{1-\gamma}$ and $\Gamma(\tau^f_{+1},\tau^w_{+1}) = \frac{1+\tau^f}{1+\tau^f_{+1}}\frac{1-\tau^w_{+1}}{1-\tau^w}$. This equation shows that the bargained surplus captured by employees is the sum of *(i)* the marginal productivity, and *(ii)* the search returns. For the worker, the returns on the search process are equal to the discounted time duration to find a job offer; for the firm, returns are instead equivalent to the discounted time duration to find a worker. These relative time spans cannot be proxied by the ratio of the average duration for these two search processes ($\theta_a = \frac{f_a}{q_a}$), as would be the case when bargaining powers or tax rates are constant.[27] However, if the workers expect that tomorrow their bargaining powers are close to zero ($\phi_{t+1} \approx 0$), the evaluation of the current match surplus is only driven by the search costs saved by the firm if the job is not destroyed ($(1-s)\frac{c_a}{q_a}$). In contrast, when the bargaining power of the worker increases ($\phi_{t+1} > \phi_t$), or if they pay more taxes, the match value must be depreciated by the firm (it expects a decrease in its bargaining power), whereas the relative time spans must be over-evaluated by the worker because its bargaining power increases. Thus, the value of the search cost is a function of the bargaining power and taxes which themselves change over time. Finally, the reservation wage is sum of the home production with the non-employment incomes.

Unskilled workers.

(i) Routine:

$$\begin{aligned} w^r(\eta) &= \frac{\gamma}{1+\tau^f}\left(y_r(\eta) + \Gamma(\tau^f_{+1},\tau^w_{+1})\frac{\phi_{+1}}{\phi}c\theta_r(\eta) + \frac{c}{q_r(\eta)}(1-s_r)\left(1-\Gamma(\tau^f_{+1},\tau^w_{+1})\frac{\phi_{+1}}{\phi}\right)\right) \\ &\quad + \frac{1-\gamma}{1-\tau^w}\left(z_r(\eta) + (1-s_r-f_r)\beta\max\{0,\mathcal{U}^n_{m,+1}(\eta)-\mathcal{U}_{r,+1}(\eta)\}\right) \end{aligned}$$

With respect to the wages of abstract jobs, the novelty comes from the reservation wage. If unemployed, workers know that they can move from routine to manual occupations if these last ones are more profitable: they take into account this new opportunity in their reservation wage. When $\mathcal{U}^n_m > \mathcal{U}_r(\eta)$, this surplus is obtained only if an unemployed worker does not find a job (with a probability $1-f_r$), net of the chance to obtain it directly after a separation (with probability s). This opportunity to move is offered only to unemployed workers: thus, this increases the reservation wage.

When $\mathcal{U}^n_m(\eta) > \mathcal{U}_r(\eta)$ and given that $U^n_m(\eta)$ is increasing whereas $\mathcal{U}_r(\eta)$ is decreasing, the

[27] More formally, in these two cases, we have $\phi_{+1}/\phi = 1$ in the first and $\Gamma(\tau^f_{+1},\tau^w_{+1}) = \frac{1+\tau^f}{1+\tau^f_{+1}}\frac{1-\tau^w_{+1}}{1-\tau^w} = 1$ in the second case

wage of routine job is

$$
\begin{aligned}
w^r(\eta) &= \frac{\gamma}{1+\tau^f}\left(y_r(\eta)+\Gamma(\tau^f_{+1},\tau^w_{+1})\frac{\phi_{+1}}{\phi}c\theta^n_m(\eta)+\frac{c}{q_r(\eta)}(1-s_r)\left(1-\Gamma(\tau^f_{+1},\tau^w_{+1})\frac{\phi_{+1}}{\phi}\right)\right)\\
&\quad+\frac{1-\gamma}{1-\tau^w}z_r(\eta)
\end{aligned}
$$

This wage is paid to workers on routine jobs, after η-type unemployed workers had moved to the market of manual jobs.

(ii) Manual (incumbent):

$$
w_m = \frac{\gamma}{1+\tau^f}\left(p_s\delta A_s+\Gamma(\tau^f_{+1},\tau^w_{+1})\frac{\phi_{+1}}{\phi}c\theta_m+\frac{c}{q_m}(1-s_m)\left(1-\Gamma(\tau^f_{+1},\tau^w_{+1})\frac{\phi_{+1}}{\phi}\right)\right)+\frac{1-\gamma}{1-\tau^w}z_m
$$

These workers are incumbent: they do not expect any mobility, except the one associated to the unemployment risk. Thus, the wage equation is the same as for the "abstract" workers.

(iii) Manual (new movers):

$$
\begin{aligned}
w^n_m(\eta) &= \frac{\gamma}{1+\tau^f}\begin{pmatrix} p_s\delta A_s+\Gamma(\tau^f_{+1},\tau^w_{+1})\frac{\phi_{+1}}{\phi}c\theta^n_m(\eta) \\ +\left(\frac{c(1-\lambda)}{q^n_m(\eta)}+\frac{c\lambda}{q_m}\right)(1-s_m)\left(1-\Gamma(\tau^f_{+1},\tau^w_{+1})\frac{\phi_{+1}}{\phi}\right)\end{pmatrix}\\
&\quad+\frac{1-\gamma}{1-\tau^w}\left(z_r(\eta)+\beta\left(\lambda(\mathcal{U}^n_{m,+1}(\eta)-\mathcal{U}_{m,+1})+s(1-\lambda)(\mathcal{U}^n_{m,+1}(\eta)-\mathcal{U}^o_{m,+1})\right)\right)
\end{aligned}
$$

The value of the opportunity to become an experimented worker is included in the reservation wage of the new movers: this changes workers' outside option $\mathcal{U}^n_{m,+1}(\eta)-\mathcal{U}_{m,+1}$ with a probability λ. But workers also know that they can lose the state of "new mover" even if they do not become experimented: they can lose their "new mover" jobs and become "old mover" unemployed workers, implying a change in their outside options $\mathcal{U}^n_{m,+1}(\eta)-\mathcal{U}^o_{m,+1}$. This event can appear with a probability $s(1-\lambda)$. In the "regular" case, we have $\mathcal{U}^n_{m,+1}(\eta)<\mathcal{U}_{m,+1}$ and $\mathcal{U}^n_{m,+1}(\eta)>\mathcal{U}^o_{m,+1}$: the expectation of the promotion leads workers to reduce their reservation wage to increase their opportunities to access this labor market state, whereas the loss of their unemployed benefits indexed to the wage of a routine job is a risk shared with the firm that hires an "new mover."

(iv) Manual (old movers):

$$
\begin{aligned}
w^o_m(\eta) &= \frac{\gamma}{1+\tau^f}\begin{pmatrix} p_s\delta A_s+\Gamma(\tau^f_{+1},\tau^w_{+1})\frac{\phi_{+1}}{\phi}c\theta^o_m \\ +\left(\frac{c(1-\lambda)}{q^o_m}+\frac{c\lambda}{q_m}\right)(1-s_m)\left(1-\Gamma(\tau^f_{+1},\tau^w_{+1})\frac{\phi_{+1}}{\phi}\right)\end{pmatrix}\\
&\quad+\frac{1-\gamma}{1-\tau^s}\left(z_m+\beta\lambda(\mathcal{U}^o_{m,+1}-\mathcal{U}_{m,+1})\right)
\end{aligned}
$$

With a probability λ, these workers become experimented manual workers and then access this new labor market: this changes their outside option by an amount of $\mathcal{U}^o_{m,+1}-\mathcal{U}_{m,+1}$.

Note that, if $\mathcal{U}^o_{m,+1} < \mathcal{U}_{m,+1}$, this leads them to accept lower wages when they are "old movers."

D.3 Market clearing conditions

The production equals the demand for final on each market:

$$\begin{aligned}
\widetilde{Y}_g &= \sum_k C_g^k \equiv C_g \quad \text{with } k \in \{ae, re(\eta), me, me^o, me^n, au, mu, ru(\eta), \upsilon\} \\
Y_s &= \sum_k C_s^k \equiv C_s,
\end{aligned}$$

where $\widetilde{Y}^g$ is the production of the intermediate goods net of hiring and entry costs:

$$\widetilde{Y}_g = Y_g - p_k K - c_a V_a - c \sum_\eta V_r(\eta) - cV_m - c \sum_\eta V_m^n(\eta) - cV_m^o,$$

and the index υ relates to the agent that receives the income $I = \mathcal{S}_g + \Omega$, which are respectively government surplus and firm dividends. Government fiscal revenues and expenditures are given by:

$$\begin{aligned}
\Theta &= (\tau^w + \tau_l^f) \left(\sum_\eta w_r(\eta) L_r(\eta) + w_m L_m + \sum_\eta w_m^n(\eta) L_m^n(\eta) + w_m^o L_m^o \right) + (\tau^w + \tau_h^f) w_a L_a \\
\Gamma &= z_a U_a + \sum_\eta z_r(\eta) U_r(\eta) + z_m (U_m + U_m^o) + \sum_\eta z_m^n(\eta) U_m^n(\eta)
\end{aligned}$$

with unemployment benefit being a function of productivity:[28] $z_i = \rho_i y_i$. This allows us to define government surplus $\mathcal{S}_g = \Theta - \Gamma$. Finally, the dividends are defined as $\Omega = \Pi_{z1} + \Pi_{z2} + \Pi_s$.

D.4 General equilibrium

Our model is a general equilibrium as labor income affects demand for goods and services, which leads to an endogenous relative price of service. However, to make the model tractable, we discard savings and discussion on the structure of public spending. Without savings, we cannot deal with welfare implications of changes in public debt or firm dividends. The general equilibrium is reached through the economic agent that receives government surplus and firm dividends and spends it on the good and service markets. [29] Alternatively, we could have shared government surplus and firm dividends among workers, using lump-sum transfers. However, we consider this assumption as unrealistic.[30] Our framework allows to be more transparent about the economic mechanisms driving welfare results for workers, based on the evolution of their

[28] While unemployment benefits are usually proportional to wages, we simplify the definition of z_i for tractable reasons. However, it does not matter so much since wage are mainly driven by movements in productivity.

[29] In Annexe D.3, this agent is denoted by subscript υ.

[30] Note that such lump-sum transfers would not alter the qualitative welfare conclusions

labor income.[31] Tax rates are all taken from institutional data. We therefore leave aside the question of the impact of changes in LMI (replacement ratios) on tax rates or public spending. Any fiscal feedback from LMI shifts is left for future research.

E Labor market institutions: Data sources

Table 2: Labor market institutions

LMI	Notation	Source	
		USA	France
Unemployment benefits Replacement rate	rr	OECD replacement rate	OECD replacement rate
Bargaining power	γ	ICTWSS[a]	ICTWSS
Employer social security contribution	τ^f	MacDaniel (2007)	MacDaniel (2007)
Employees social security contributions	τ^w	MacDaniel (2007)	MacDaniel (2007)
Minimum wage	$\frac{w_{\min}}{mean(w)}$	FRED, gross hourly	INSEE, equivalent annual

a: Database on Institutional Characteristics from Trade Unions, Wage Settings, State Intervention and Social Pact (ICTWSS) average of union density and union coverage

[31] Dealing with savings is left for future research as the size of the model is already very large

F Model calibration

F.1 Calibration

The calibration is quarterly. Some parameters are considered as common to all countries. These parameters include preferences, and technology:

$$\Phi_1 = \{\beta, \rho, \nu, \sigma, \mu, \alpha, \underline{\eta}, \overline{\eta}, A, A_s, \delta, \lambda\} \quad \text{with } dim(\Phi_1) = 12.$$

For the labor market, the following parameters are country-specific:

$$\Phi_2 = \{\psi, \Upsilon_a, \Upsilon_r, \Upsilon_m, s_a, s_r, s_m, c_a, c\}_{US,F} \quad \text{with } dim(\Phi_2) = 18,$$

as well as the technological change and the drift in the supply of skilled labor:

$$\Phi_3 = \{p_k(0), \vartheta_{pk}, p_k(T), L_a(0), \vartheta_{La}, L_a(T)\}_{US,F} \quad \text{with } dim(\Phi_3) = 12,$$

where exogenous variables are constrained by the following process::

$$x(t) = \begin{cases} x(0) & \text{if } \ t < t_{x0} \\ x(T) + (x(0) - x(T)) \exp(-\vartheta_x (t - t_{x0})^2) & \text{Otherwise} \end{cases} \tag{24}$$

for $x = p_k, L_a$, in the United States or in France; T is the length of the simulated variables; $x(0)$ and $x(T)$, for $x = p_k, L_a$ are the initial and the terminal values; ϑ_x, for $x = p_k, L_a$, corresponds to the speed at which the variable adjusts to its final value. For the estimation, we assume that changes in the price of capital and in the education process begin respectively in $t_{k0} = 1975$ and $t_{L_a0} = 1960$ in the United States, whereas for France we set $t_{k0} = 1975$ and $t_{L_a0} = 1970$.

The total number of parameters is 42. The empirical target are

$$\Psi_T = \left\{ \begin{array}{l} N_{a,i}(0), N_{r,i}(0), N_{m,i}(0), N_{a,i}(T), N_{r,i}(T), N_{m,i}(T), \\ E_i[N_a], E_i[N_r], E_i[N_m] \end{array} \right\}_{i=US,F} \quad \text{with } dim(\Psi_T) = 18$$

Restrictions. In order to identify the unknown parameters, it is necessary to introduce $42 - 18 = 24$ restrictions. Using external information, we calibrate $\Phi_i^c \in \Phi_i$, for $i = 1, 2, 3$:

$$\begin{aligned} \Phi_1^c &= \{\beta, \mu, \nu\} \quad \text{with } dim(\Phi_1^c) = 3 \\ \Phi_2^c &= \{\psi, s_a, s_r, s_m, c_a, c\}_{US,F} \quad \text{with } dim(\Phi_2^c) = 12 \\ \Phi_3^c &= \{L_a(0), L_a(T)\}_{US,F} \quad \text{with } dim(\Phi_3^c) = 4 \end{aligned}$$

In addition to these 19 restrictions based on external information, we assume that *(i)* the efficiency of the labor market of high skilled workers is the same across countries (i.e., $\Upsilon_{a,US} = \Upsilon_{a,F}$), *(ii)* the path of the technological progress is identical across countries (i.e., $p_{k,US}(0) = p_{k,US}(0)$), normalized to unity, $\vartheta_{pk,US} = \vartheta_{pk,F}$ and $p_{k,US}(T) = p_{k,F}(T)$.[32] Thus, with these five

[32]This restriction does not mean that the level of the technology is the same on both side of the Atlantic:

additional restrictions, the number of unknown parameters (Φ_i^u, for $i = 1, 2, 3$) becomes equal to 18, where $dim(\Phi_1^u) = 9$, $dim(\Phi_2^u) = 5$ and $dim(\Phi_3^u) = 4$, and the model is just-identified.

Parameter based on external information. Table 3 summarizes calibrated parameters. There is a first set of parameters that is not country-specific. The discount factor β is such that

Table 3: Model parameters values based on external information

Matching								
c_a	c	ψ	$s_{a,US}$	$s_{r,US}$	$s_{m,US}$	$s_{a,F}$	$s_{r,F}$	$s_{m,F}$
0.5	0.3	0.5	0.05	0.085	0.13	0.04	0.045	0.11
Preferences				Labor supply composition				
β	μ	ν		$L_{a,US}(0)$	$L_{a,F}(0)$	$L_{a,US}(T)$	$L_{a,F}(T)$	
4%	0.5	0.5		0.17	0.085	0.238	0.1513	

the annual real interest rate is 4%. The elasticity of the matching function is set to 0.5, which is consistent with the estimates reported in Petrongolo & Pissarides (2001). The calibrations of the vacancy posting costs $\{c_a, c\}$ are based on the results of Barron et al. (1997) and Barron & Bishop (1985). These authors suggest that an amount to 17% of a 40-hour workweek.[33]. For the low-skilled workers, we set $c = 0.3$ because this corresponds to 17% of the average production of workers on routine and manual occupations. For the skilled workers, we suppose that the work time required to process each application is 1.66 larger, leading us to set $c_a = 0.5$.[34] This value lies within the range found in the literature: Acemoglu (2001) and Krause & Lubik (2006) suggest $\frac{c_a}{c} > 1$, whereas $\frac{c_a}{c} = 1.15$ in Angelopoulos & Malley (2015) and 4 in Krause & Lubik (2006) and Hagedorn et al. (2014). Finally, we arbitrary set to $\mu = \nu = 0.5$ the values of the share parameters respectively in the production and utility functions.

The second set of parameters are country-specific: these are job separation rates and the shift of the labor supply composition.

- *Job separation rates.* In Elsby et al. (2008), the exogenous inflow rates from employment to unemployment are respectively equal to 0.108 in the United States and 0.021 in France (i.e., five times lower for the French workers). In Shimer (2012), the aggregate separation rate is between 0.0675 per quarter (Men age 25–54) and 0.105 (All population) for the United States. In Le Barbanchon et al. (2015), the job separation is estimated to be equal to 0.051 per quarter using administrative data. We set intermediate values of these three previous studies, i.e. $\mathbb{E}_i[\mathbb{E}_t[s_{t,i,US}]] \approx 0.08$ and $\mathbb{E}_i[\mathbb{E}_t[s_{t,i,F}]] \approx 0.05$, leading to a more conservative gap between the United States and France (less than twice the size in the United States than in France). With regard to the dispersion of the quarterly rates of separation among occupations: We observe that unemployed rates by occupation in

the endogenous level of capital in ICT controls for heterogeneous initial endowments between France and the United States (more than twice as large in the United States).

[33]More precisely, nine applicants for each vacancy filled, with two hours of work time required to process each application

[34]Job creation costs consist of costs for recruitment, screening, and training. Acemoglu (2001) argue that job creation costs are likely to be larger for high-wage jobs. This supports the view that job creation costs for abstract jobs are larger than for low-wage jobs.

the United States[35] are approximatively 2% for the abstract, 5% for the routine, and 8% for the manual occupations. Thus, assuming that the separation rate account for 40% of the unemployment gaps between occupation, which is the share of the separations in the unemployment dynamics (see Fujita & Ramey (2009)), we obtain the quarterly job separation rate by task reported in Table 3, satisfying $\mathbb{E}_i[\mathbb{E}_t[s_{t,i,US}]] \approx 0.08$. For France, we simply multiply these rates by $\mathbb{E}_i[\mathbb{E}_t[s_{t,i,F}]]/\mathbb{E}_i[\mathbb{E}_t[s_{t,i,US}]]$ in order to match the average job separation rate in France.

- *Share of the labor supply for abstract jobs.* We choose to pin down L_a that is consistent with the observed employment level in abstract jobs N_a and the non-employment rate in the pool of abstract jobs, denoted nn_a. Hence, $L_a = N_a/(1 - nn_a)$. We choose to approximate the rate of people that are not employed in the segment of the abstract tasks as the non-employment rate of the bachelor's degree or more. These rates has been stable in the United States, around 20%, whereas in France, they slightly increase from 15% in the 80s to 18% in 2008. Using the formula $L_{a,US}(\tau) = N_{a,i}(\tau)/(1 - nn_{a,i}(\tau))$, for $i = US, F$ and $\tau = 0, T$, we obtain the values reported in Table 3.

Estimation. For the estimation, we assume that changes in the price of capital and in the education process begin respectively in $t_{k0} = 1975$ and $t_{L_a0} = 1960$ in the United States, whereas for France we set $t_{k0} = 1975$ and $t_{L_a0} = 1970$.[36] The unknown parameters are then estimated by solving $\min_{\Phi^u} ||\Psi(\Phi^u) - \Psi_T||$, with $\Phi^u = \{\Phi_1^u, \Phi_2^u, \Phi_3^u\}$. The model is non-stationary and non-linear, which requires an innovative solution method. The algorithm is presented in Appendix G.

F.2 Model fit

Figures 20 and 21 summarize the model's predictions with regard to aggregate employment levels (for total population and for unskilled workers) and employment shares across occupational groups. The model's empirical targets include employment (aggregate and by task) at the beginning and the end of the sample as well as the average value. However, there is no guarantee that the model is then able to fit the evolution over time of each time series. We check here that the model fit along this dimension is satisfactory.

For the US economy (Figure 20), the model matches the aggregate upward trend, and the downward trend for unskilled employment, measured in the model as the sum of routine and manual jobs. The model is also able to capture the fall in the French employment level until the mid-1990s and its subsequent rebound (Figure 21). This resulted in an increase in the employment of unskilled workers, explained by a break in the decline of routine jobs and an increase in manual jobs.

[35] See BLS: `https://www.bls.gov/web/empsit/cpseea30.htm`

[36] These starting dates are chosen because they correspond to the product launch of the first IBM personal computer, and the take-off of the number of students in universities. Justiano et al. (2010), Karabarbounis & Neiman (2014) also report a sharp decline in the price of investment goods, starting in 1975.

Figure 20: Employment levels and shares. *US economy*

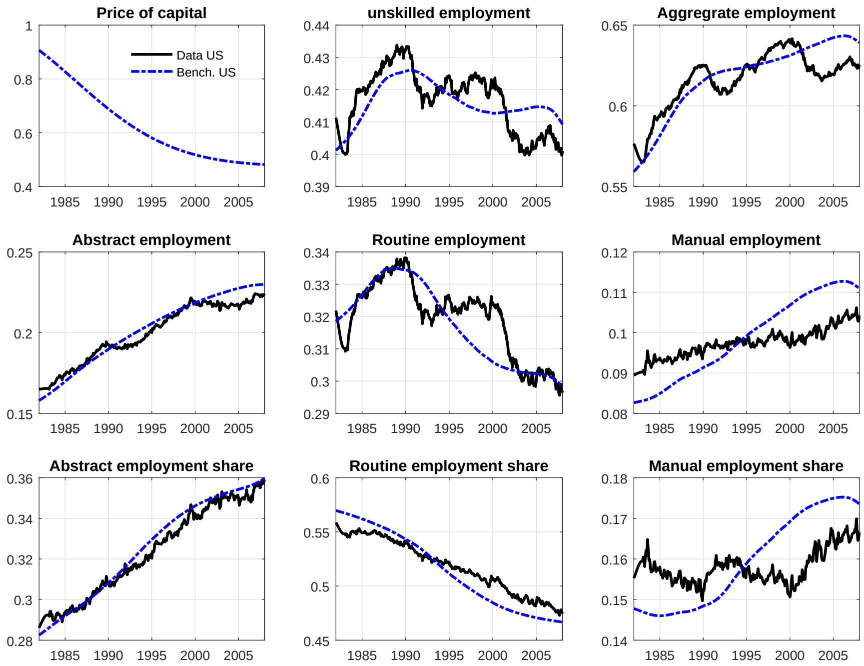
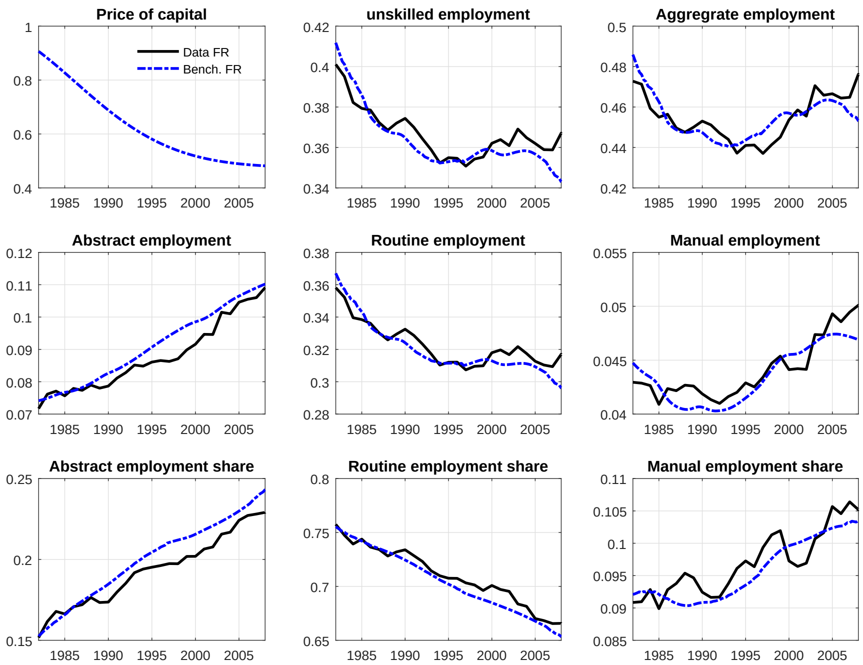


Figure 21: Employment levels and shares. *French economy*



G Numerical method used to solve the model

G.1 Overview of computational difficulties

Solving the model is challenging. Several elements make the computation of the dynamic challenging.

- First, the job polarization involves a non-stationary environment because of structural changes in the economy. The main difficulty is the occurrence of regimes only during the transitional path, and not at the steady. As a result, standard solution methods involving approximation of the dynamics around a unique steady state are inappropriate.
- Second, we have heterogeneous agents. The problem is currently solved with 100 ability levels $\eta \sim \mathcal{U}(\underline{\eta}, \overline{\eta})$, which makes the computation burdensome.
- Third, along the transitional path, we face a highly non-linear environment. The reasons behind the non-linearity is threefold:
  1. Along the transitional path, the minimum wage can bind or not in some segments of the labor market, leading to several regimes in the economy.
  2. The existence of rigid wage in the form of a minimum wage may cause firms to run negative surplus, thereby leading to firms' closure and introducing a scrapping-time.
  3. Occupational choices involves also discontinuities as workers of different abilities leave the routine labor market.

  We then have to deal with occasionally binding constraints for each ability level. Changes in occupations, binding minimum wages and firms' closure are all endogenous events.
- Fourth, there are general equilibrium effects: the relative price of service is such that good and service markets clear. This relative price also affects the relative productivity levels across sectors, which feeds back on occupational choices, employment levels in each sector and the supply in the good and service markets. In turn, those changes are likely to affect the relative price of service, and so on. As a result, we need to find a fixed point over general equilibrium effect for each period along the transitional path.

G.2 Overview of the algorithm

Standard procedures can no longer be used because of the huge number of discontinuities. This leads us to propose an original algorithm for the numerical solution of the model. The algorithm aims at finding a "fixed point" for a trajectory between an initial steady state and a terminal steady state, given that, during this adjustment process, exogenous variables, such as the policy tools, can change. The numerical method is presented in the case of perfect forecast for the policy instruments.

We use the block-recursive aspect of the Diamond–Mortensen–Pissarides (DMP) model that is cast into two sub-routines. We first solve for the paths of the forward variables, given an initial guess one the dynamics of backward variables. Thereafter, the backward variables trajectories are obtained by iterating on their law of motion. Given new trajectories for the state variables, a new trajectory for the forward variable is calculated. This procedure is repeated until convergence of both the backward and the forward variables.

G.3 Detailed algorithm

G.3.1 Notations

- T is the simulation length.
- $\{x_t\}_{t=0}^{T}$ stacks the trajectory of all **endogenous** state (backward) variables. x corresponds to all different employment and unemployment stocks.
- $\{y_t\}_{t=0}^{T}$ stacks the trajectory of all **endogenous** control (forward) variables. y corresponds to all different value functions, tightness, prices, wages, productivity values, capital levels and consumption levels.
- $\{z_t\}_{t=0}^{T}$ stacks the trajectory of all **exogenous** disturbance that for which we perfectly know their value. It corresponds to the value of the observed LMIs (replacement rate, minimum wage, bargaining powers as well as employers and employees social security contributions).
- $\{p_{k,t}\}_{t=0}^{T}$ and $\{L_{a,t}\}_{t=0}^{T}$ are two disturbances whose law of motion are define is the core of the paper. The important aspect here is that they do not depend on endogenous variable or exogenous disturbances.
- Θ stands for the set of parameters.

G.3.2 General problem

The general problem can be summarized by the following system of equations:

$$\begin{aligned} x_t &= g(x_{t-1}, y_{t-1}; \Theta) \\ y_t &= f(x_{t+1}, y_{t+1}, z_{t+1}; \Theta) \\ p_{k,t} &= h_1(t; \Theta) \\ L_{a,t} &= h_2(t; \Theta) \end{aligned}$$

G.3.3 Step-by-step algorithm

Step 1 *Set the parameters* Θ *and get the trajectories for the shocks* $\{p_{k,t}\}_{t=0}^{T}$ *and* $\{L_{a,t}\}_{t=0}^{T}$.

Step 2 *Guess an initial trajectory*[37] *for the state variables* $\{x_t^0\}_{t=0}^T$ *and for the control variables* $\{y_t^0\}_{t=0}^T$. *For simplicity, we assume in a first time that they are all constant. Since the states variables correspond to the stocks of employment and unemployment, the only constraint that must be imposed is* $\sum x_t = 1$ *every period. For the controls, they are all set to one* $\forall t$ *in the first place.*

Step 3 *Given the terminal condition of the shocks* $p_{k,T}$ *and* $L_{a,T}$*, the terminal condition of state variables* x_T^0 *and the shock processes* z_t *at time* $t = T$*, recalculate the terminal condition for the control variables* y_T *using a fixed-point method.*

Step 4 *Given the exogenous shock and the initial trajectory of the state variables* $\{x_t^0\}_{t=0}^T$*, solve for the path of the control variables by iterating backward*[38]*:*

$$\begin{aligned}
y_{T-1} &= f(x_T^0, y_T, z_T; \Theta) \\
y_{T-2} &= f(x_{T-1}^0, y_{T-1}, z_{T-1}; \Theta) \\
y_{T-3} &= f(x_{T-2}^0, y_{T-2}, z_{T-2}; \Theta) \\
\vdots \quad &\quad \vdots \\
y_0 &= f(x_1^0, y_1, z_1; \Theta)
\end{aligned}$$

Step 5 *Given the initial condition of the shocks* $p_{k,0}$ *and* $L_{a,0}$*, the new initial condition of control variables* y_0 *and the shock processes* z_t *at time* $t = 0$*, recalculate the initial condition for the control variables* x_0 *using a fixed-point method.*

Step 6 *Given the initial conditions of the states* x_0 *(from* **Step 2***) and the new path of the controls* $\{y_t\}_{t=0}^T$*, solve for the path of the state variables by iterating forward using the laws of motion:*

$$\begin{aligned}
x_1 &= g(x_0, y_0; \Theta) \\
x_2 &= g(x_1, y_1; \Theta) \\
\vdots \quad &\quad \vdots \\
x_{T-1} &= g(x_{T-2}, y_{t-2}; \Theta) \\
x_T &= g(x_{T-1}, y_{T-1}; \Theta)
\end{aligned}$$

[37] Superscript zero to x_t^0 and y_t^0 stands for the initial guesses.

[38] It should be noted that given the highly non-linear nature of the system of equations in $f(.)$, we need a root-finding procedure to pin down some control variables at each period t. For that purpose, we use a Newton–Raphson algorithm. Furthermore, this step involves the checking of whether the aforementioned constraints (minimum wage, occupation, scrapping) are binding or not. This involves an adaptive algorithm which tests for the binding constraints.

Step 7 *Check if the new trajectories of the states* $\{x_t\}_{t=0}^T$ *and the controls* $\{y_t\}_{t=0}^T$ *are different from the one in* ***Step 2*** *(i.e.,* $\{x_t^0\}_{t=0}^T$ *and* $\{y_t^0\}_{t=0}^T$*, respectively). We use a Euclidian norm and target and criterion of* 10^{-8}*:*

$$\frac{||x - x^0||}{||x^0||} \leq 10^{-8}$$
$$\frac{||y - y^0||}{||y^0||} \leq 10^{-8}$$

Step 8 *If it is not the case, then define:*

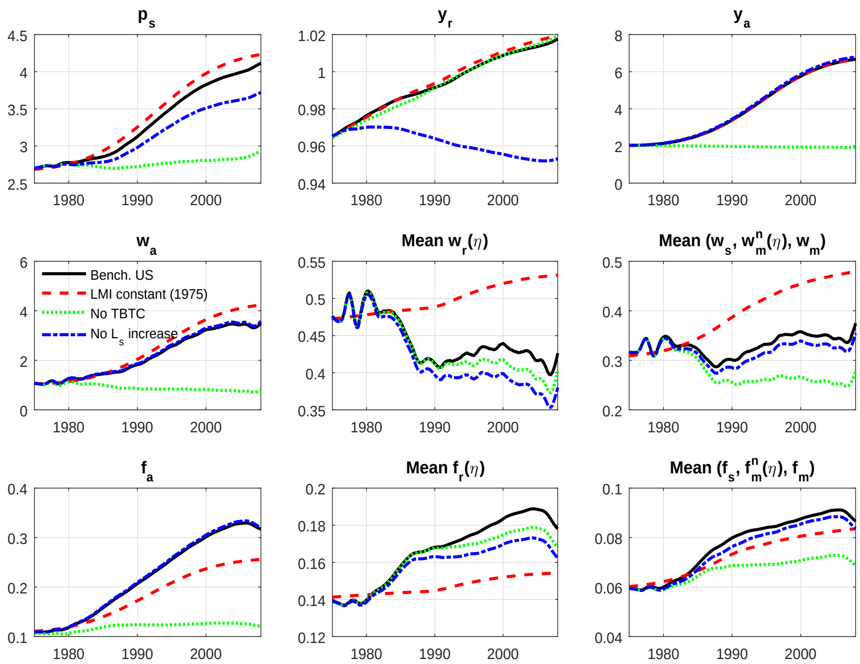
$$\begin{aligned} \{x_t^0\}_{t=0}^T &= \{x_t\}_{t=0}^T \\ \{y_t^0\}_{t=0}^T &= \{y_t\}_{t=0}^T \end{aligned}$$

and go back to **Step 3**.

H Additional graphs on the polarization analysis: Benchmark case

For routine jobs and manual job wage are averaged using the employment weight for each categories.[39]

Figure 22: Productivity, average wages, and job finding rates. *US economy.*



[39]The productivity for routine job does not include the skill component η. By multiplying y_r by η, we have the productivity for each skill $y_r(\eta)$.

Figure 23: Productivity, average wages, and job finding rates. *French economy.*