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Abstract

This paper extends on French data the previous findings on US data: employment and wage growth have been more important in the lower and upper tail of the job quality distribution. The originality of the paper is to argue that the diffusion of ICT cannot explain alone the polarization at the lower tail of the distribution. However, when combined with population aging, our framework predicts a progressive concentration of employment in the service sector. These results are confirmed by French data. In addition, we develop an analytical framework to shed light on the economic mechanisms behind our empirical finding. We lay stress on the Balassa effect on the supply side and aging on the demand side.

JEL Codes : J14, J21, J24, O33

Keywords : Job Polarization, Occupational Structure, Aging

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1 Introduction

This paper seeks to gain insights on the impact of aging on the recent labor market dynamics. More precisely, the economic literature points towards biased technological progress as the main factor behind the observed job polarization between "lousy and lovely" jobs (see Goos and Maning (2007), Autor, Levy, and Kearney (2006) or Spitz-Oener (2006)). The idea being that technology can replace human labor in routine tasks (manual or cognitive) but cannot replace human labor in non-routine tasks. Whereas routine tasks are mainly implemented by medium qualified workers (for example, book-keeping, clerical work and repetitive production tasks), non routine tasks can either be implemented by the least qualified workers (i.e. taxi driver, hairdresser, etc. referred to as "manual non routine tasks") or by the highest qualified workers (i.e. educated professionals and managers, referred to as "abstract tasks"). Because routine tasks are easily automated, new technologies have gradually replaced medium qualified workers in these tasks.

The gradual substitution of routine labor by machines has, on the one hand, improved the productivity of labor occupied in non-routine abstract positions, since new technologies facilitate and accelerate the access to abundant information and analysis. On the other hand, there is the appearance of a mass of jobless medium qualified workers. Part of this mass may remain unemployed[1], whereas another part may be reallocated towards more labor demanding sectors. Obviously, in spite of the increased demand for qualified labor in abstract positions, there is a skill mismatch problem since medium qualified workers do not have the required qualification to apply to this type of non-routine jobs. They will have thus to reallocate towards manual non routine positions (see Goos and Maning (2007)). But why the demand for these jobs should rise?

The literature is far from an unanimous view concerning the reasons behind the increased demand for labor input in non routine manual jobs. Initially, most of the literature simply focused on the progression of wage inequalities along the distribution. The works by Lemieux (2006) or Autor, Katz, and Kearney (2008) found that wage inequalities between the ninth and the fifth decile had increased more than wage inequalities between the ninth and the first decile, suggesting the existence of a rising demand for jobs at the top and at the bottom of the distribution or, at least, a decreasing demand for jobs at the middle of the distribution. Later works by Autor, Levy, and Kearney (2006), Spitz-Oener (2006), Maurin and Thesmar (2004) or Goos and Maning (2007) confirmed the previous finding. These papers find that labor input in routine positions (middle

[1] Cheron, Langot, and Moreno-Galbis (2009) show that the diffusion of new technologies has fostered a gradual increase in the relative unemployment rate of medium skilled workers.

of the wage distribution) has gradually been replaced by cheaper and more productive machines, which have also allowed to improve the productivity of labor input in abstract tasks (top of the wage distribution). The productivity of manual non routine tasks has remained unaffected. This type of positions are difficult to automate or outsource since they require interpersonal and environmental adaptability as well as direct physical proximity.

None of the previous papers really succeeds in explaining why novel technologies should have increased the demand for manual non routine labor. Some of them, such as Goos and Maning (2007), simply claim that medium qualified workers have been reallocated towards manual positions, but no reason is given to justify the rise in the demand for this type of labor.

A recent work by Goos, Maning, and Salomons (2010) based on 16 European countries finds that the routinization hypothesis is the most important factor behind the observed shifts in the employment structure. They also conclude that globalization has decreased the demand for jobs that are offshorable, although the estimated impact is smaller relative to the impact of technological change. Little support is also found for the hypothesis that changes in product demand are driven by income inequality effects[2].

Autor and Dorn (2010) use the elasticity of substitution between goods and personnel-services to justify the progressive reallocation of workers replaced by machines in the good sector towards the personnel-service sector. According to these authors, if goods and services are sufficiently complementary, the progressive decrease in the relative price of goods (fostered by productivity gains linked to the diffusion of new technologies) should yield a rise in the demand for personnel-services. However, in their paper, Autor and Dorn (2010) do not justify why suddenly, over the past ten years, goods and personnel-services should have become complementary.

The originality of our paper lies in providing a potential explanation to the increase in the complementarity between goods and personnel-services proposed by Autor and Dorn (2010). We claim that population aging can justify the change in the aggregate substitution/complementary relationship between goods and personnel-services. Our idea is that, whereas for young workers goods and personnel-services are rather substitutes, for older people they are complements. Obviously, rather than focusing on the elasticity of substitution, we could have adopted Clark (1957)'s perspective and argue that the increase in the income of old workers over the past decades yielded a rise in their demand for services, whose income elasticity of the demand is greater than one. Because, the proportion of old consumers in Western countries has continuously increased over the past two

[2]Clark (1957) argued that the income elasticity of the demand for services is greater than unitary, in which case a general rise in income will tend to shift employment towards service-intensive occupations.

decades, this demand effect should have favored a progressive increase in the demand for services. However, we prefer to remain as close as possible to Autor and Dorn (2010)'s framework, since Goos, Maning, and Salomons (2010) find little support to the hypothesis of changes in demand driven by income. We then simply claim that, for old people, goods and services are complements (see Luhrmann (2008) for an estimate of age-related elasticities of substitution). When the relative price of goods decreases (induced by technological progress), their demand for services increases. We illustrate these economic mechanisms empirically and theoretically. From an empirical point of view, we use the French Labor Force Survey (1993-2007) to show the polarization of employment among "lovely and lousy" jobs in France. We underline then the importance of the increase in employment in personnel services as the main determinant of job polarization at the bottom of the distribution. Finally, we propose several tests to prove the role of aging as responsible for the increasing demand for personnel services.

From a theoretical point of view, we add to a simplified Autor and Dorn (2010)'s framework, where we only consider two input factors, an heterogeneous demand for goods and services coming from young and old people. Our analytical approach allows us to shed light on the conditions that generate an increase in service employment.

The paper is organized as follows. Section 2 provides evidence of job polarization in the French labor market over the past 15 years, with a significant employment and wage growth rates at the bottom and top of the job quality ladder. The rise in employment and wage suggests an expanding demand for jobs at the bottom of the wage distribution. These jobs appear to be personnel service occupations. The data also suggests that the rise in service occupation jobs is linked to new technologies (ICT) and aging, which constitutes the first originality of our paper. Section 3 presents the second contribution of our paper by shedding light on the economic mechanisms behind the interaction between aging and ICT, laying stress on the interaction between labor allocation away from routine tasks and the rising demand for personal service occupations due to aging. Section 5 concludes.

2 Job polarization and aging on French microdata

In this section, we provide evidence that France has experienced a job polarization over the past 15 years, with a significant employment growth for jobs at the top and bottom of the wage distribution. We also want to know whether service occupation jobs are indeed at the lower end of the wage distribution and characterized by a rapid employment growth.

Our empirical analysis is based on 15 successive waves of the French Labor Force Survey (1993 through 2007). Individuals report information on worked hours, hourly pay, occupation and industry. The French LFS provides the occupation for each employed individual, among a list of 350 possible occupations such as "gardener","messenger", "clerks in banking activities", "financial managers" [3], etc. This variable captures the job. Some occupations are characterized by a very general definition and a large number of employed individuals. In this case, we disaggregate these jobs by industry [4]. For instance, secretaries are divided into secretaries in the food industry, in the car industry, etc ... This leaves us with 452 occupations each year.

2.1 Change in the employment structure in France

The French LFS allows us to have a look at trends in the quality of jobs. As in Goos and Maning (2007), quality is proxied by the median hourly wage for each job at the beginning of the period. We first relate the job quality in 1993 with the average subsequent change in log employment from 1993 through 2007 [5]. Figure 1 presents the average change in log employment in the 1993-2007 period for each job quality (proxied by its median wage). The size of the circles denotes the employment level in 1993. We also report a quadratic fit of the average employment growth on job quality. Panel (i) of Figure 1 suggests an U-shaped relationship between employment growth and job quality [6]. Over the past 15 years, middling jobs have been characterized by a low employment growth while the rise in employment has been larger for jobs at the bottom and at the top of the wage distribution.

At the lower end of the job quality distribution, two jobs are characterized by a high employment level in 1993 and a strong subsequent employment growth. These large circles correspond to occupations related to child care and house cleaning. More generally, low paid jobs in 1993 with rising employment between 1993 and 2007 are service occupations. This is clearly observed in Panel (ii) of Figure 1 which reveals that, as soon as we do not include in the analysis personnel service

[3] With this range of possible jobs, the wage distribution captures the low paid occupations as well as high paid jobs. However, the number of observations in top jobs is particularly low in all surveys. The sample does not capture the increase in wage inequality due to the top 1% of the wage distribution (Landais (2008)).

[4] Appendix 6 provides a full description of the data.

[5] Unfortunately, we could not use LFS prior to 1993 because of a drastic change in industry classification. It was not possible to obtain consistent industry codes over time. Since some jobs are defined as a specific occupation in a specific industry, this prevents us from using pre-1993 surveys.

[6] We choose to consider here the change in log employment over the 1993-2007 period as in Goos and Maning (2007). Autor and Dorn (2010) examine the change in employment share. We check that the relationship between job quality and change in employment share is still U-shaped, thereby suggesting a job polarization.

occupations, the U-shape curve disappears.

One might think that the feminization of employment can explain this job polarization, with women accounting for the growth in relatively low-paid occupations. But, as figure 2 shows, one observes similar patterns for male and female employment considered separately in the 1993-2007 period. Results are not modified with respect to the pooled sample. Jobs at the bottom or at the top of the wage distribution have benefitted from much larger growth rates than jobs at the middle of the distribution, determining an U-shape progression of the employment structure[7].

In sum, Figures 1 and 2 support the view that job polarization has occurred over the past 15 years in France and that the increase in the employment share at the bottom of the wage distribution comes mainly from personnel services occupations. This can also be seen from Table 1 that ranks occupations from highest-paid to lowest-paid. For each occupation, Table 1 reports the average log change in employment and wage. Among the fastest expanding occupations (panel (a) of Table 1) are managers and executives but also the lowest-paid jobs (panel (c)) such as child care and transportation services. The largest declines in employment (panel (b)) are observed for middling occupations such as secretaries, office clerks and some skilled workers in specific industries. Panel (d) of Table 1 reports the average change in log employment over 1993-2007 for the top 10% jobs (ranked by the median 1993 wage), bottom 10% and middling jobs (identified as job in the 45-55% percentiles of the 1993 wage distribution). The table confirms the fast employment growth at the top and bottom of the job quality ladder while middling occupations have been characterized by a decline in employment. Furthermore, most of the employment growth observed at the bottom of the wage distribution comes from service occupation jobs [8].

These facts, also found by Autor and Dorn (2010) on US data, motivate our investigation on service employment. We investigate in the next section how aging, interpreted as a demand shift for personnel services, has affected growth in service employment over the past 15 years.

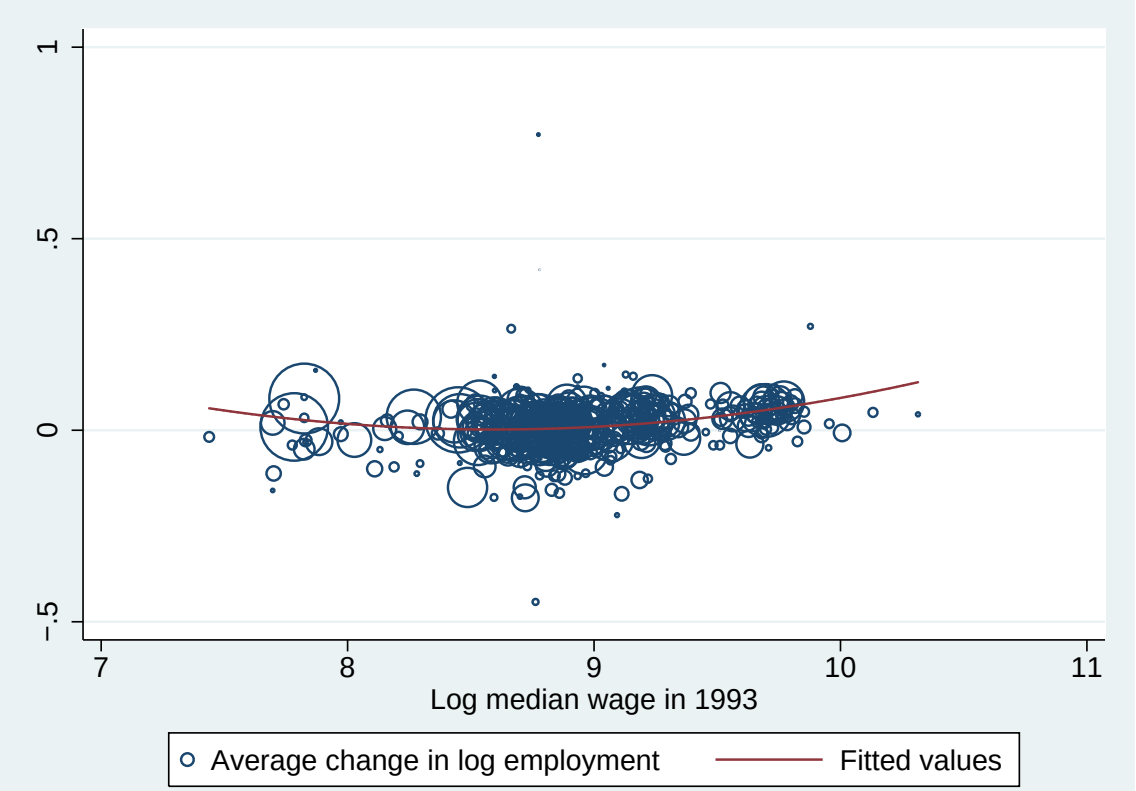
2.2 Growth in service employment and aging

In this subsection, we analyze the relationship between aging and growth in service employment after including control variables. As in Autor and Dorn (2010), our empirical investigation relies on a panel of regional data. In each region, each year, we compute the share of service employment in total employment. The change in this share, for each region, each year constitutes our dependant

[7]When personnel service occupations are not included in the analysis the U-shape progression almost disappears, underlining the major role played by these jobs in the polarization process. Figures available upon request.

[8]The list of jobs considered as service occupations is reported in Appendix 7.

(i): Benchmark



(ii): No personnel services

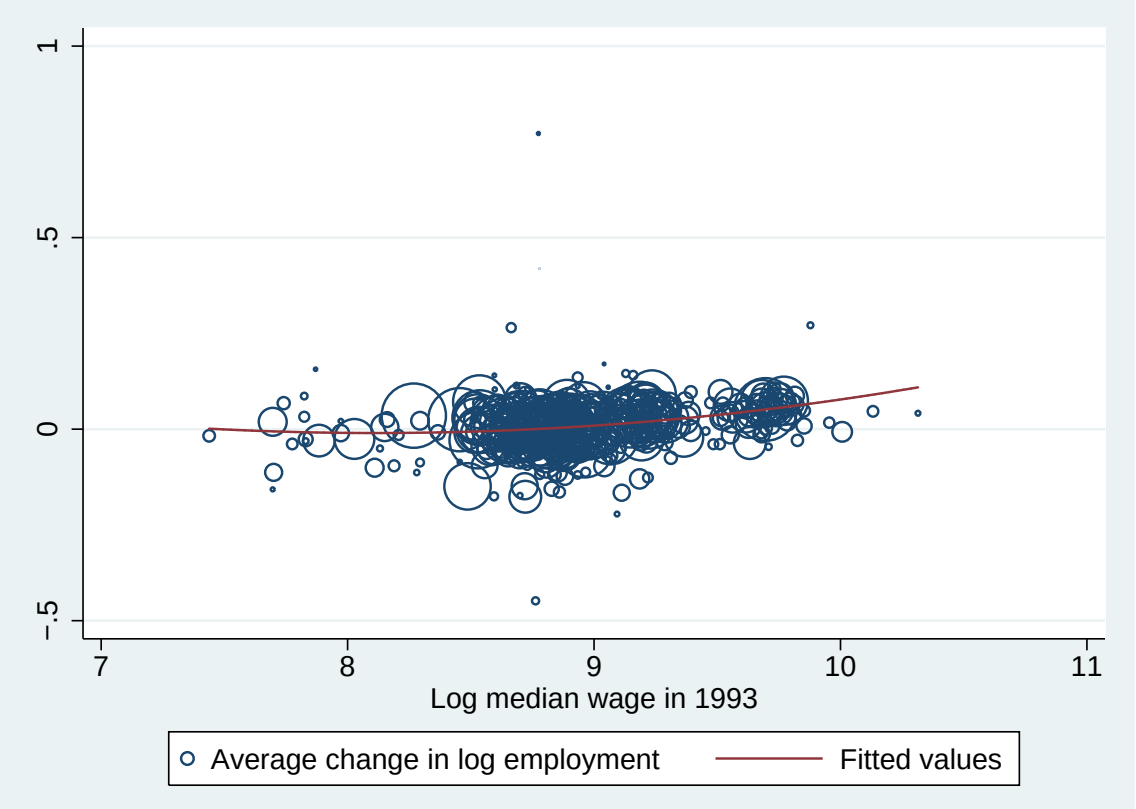
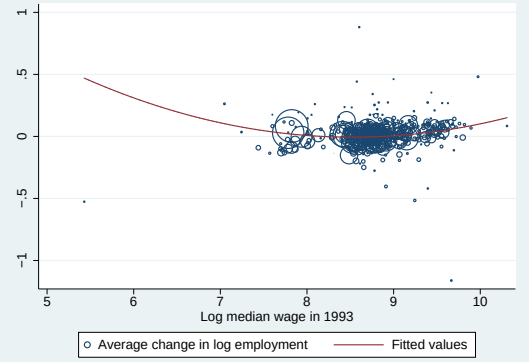


Figure 1: Average employment growth by job median wage (1993-2007).

Table 1: Change in log employment (dlnN) and change in median wage (dlnW) over 1993-2007 for occupations ranked by their median 1993 wage (lnW1993)

	$\ln W_{1993}$	dlnN	dlnW
(a) Top paying jobs			
Managers of small firms, administrative or financial department	10.3145	0.1159	0.0133
Flying personnel	10.1320	0.0691	0.0270
Managers in big firms, administrative, financial or sale department	10.0069	0.0384	0.0100
Technical director in a big firm	9.9547	0.0543	0.0100
Engineer and executive in production specifications	9.8782	0.0302	-0.0018
Physicians	9.8522	0.0321	0.0440
Engineer and executive in research	9.8522	0.0327	-0.0191
(b) Middling occupations			
skilled coach builder	8.8292	0.0222	0.0244
office clerk in accounting and financial department, transportation industry	8.8341	-0.0095	0.0237
office clerk in accounting and financial department, food industry	8.8367	0.0478	0.0180
office clerks, misc, intermediate good industry	8.8381	-0.0163	0.0241
secretary, engineering industry	8.8393	-0.0764	0.0284
salesman in food	8.8393	-0.0488	0.0174
skilled worker in extraction	8.8393	-0.0304	0.0158
skilled worker in weather-stripping	8.8393	-0.0132	0.0253
warehouseman in intermediate good industry	8.8438	-0.0019	0.0226
unskilled worker in sorting, wrapping and delivery activities, engineering industry	8.8441	-0.0133	0.0166
secretary in car industry	8.8472	-0.0958	0.0317
(c) Lowest paying jobs			
child care	7.8240	0.0845	0.0473
unskilled worker in sorting, wrapping and delivery activities, in health services	7.8240	0.0322	0.0297
warehouse men in health services	7.8240	0.0354	0.0760
cleaner and staff in private homes	7.7832	0.0348	0.0452
transportation services in health industry	7.7407	0.0761	0.0387
unskilled worker in mechanics	7.6962	-0.1571	-0.0078
cleaner in construction industry	7.4384	0.0390	0.1108
(d) top 10%	9.6098	0.0392	0.0130
middling occupation (45-55%)	8.8316	-0.0053	0.0219
bottom 10%	8.0717	0.0211	0.0368
service occupations	8.3073	0.0374	0.0318
total	8.8393	0.0079	0.0224

(i): Benchmark (women)



(iii): Benchmark (men)

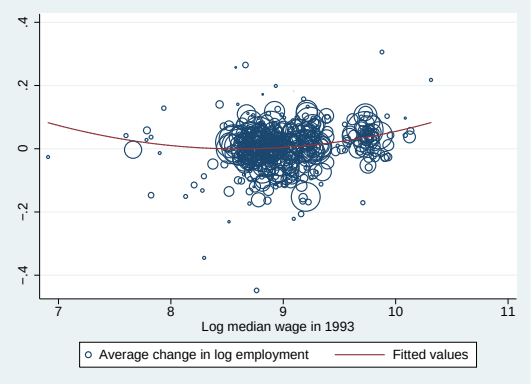


Figure 2: Average employment growth for men and women by job median wage (1993-2007).

variable. With 21 regions and 14 changes in service employment share (1993-2007) yields a panel data of 294 observations [9].

Our empirical exercise mimics Autor and Dorn (2010)'s investigation on US commuting zones. We extend their analysis on French data and lay stress on the demand shift associated with aging. The estimated equation is

$$d\left(\frac{N_{i,t}^{service}}{N_{i,t}}\right) = \alpha + \beta\ old_{i,t-1} + \gamma X_{i,t} + e_{i,t}$$

where $d\left(\frac{N_{i,t}^{service}}{N_{i,t}}\right)$ denotes the change in service employment share $\left(\frac{N_{i,t}^{service}}{N_{i,t}} - \frac{N_{i,t-1}^{service}}{N_{i,t-1}}\right)$ in region i and year t. Service jobs include the following occupations : house cleaning, child care, janitors, ... Appendix 7 provides the list of service occupations.

Our paper explores the view that the rise in service employment is demand driven, in particular, by aging individuals. This effect is measured by the share of retired individuals aged 60 and more in the total population, denoted $old_{i,t-1}$ in region i and year $t-1$. This share is lagged in order to capture an exogenous effect of aging on the change in service employment share. If our hypothesis is confirmed by the data, we expect $\beta > 0$.

$X_{i,t}$ denotes a set of control variables that include

- lagged share of routine jobs (ratio of the number of employed individuals in routine jobs to total employment in region i and year $t-1$). This variable proxies the technological change

[9] See Appendix 7. Fewer observations are reported in the subsequent tables because of missing values on some control variables.

stressed in Autor and Dorn (2010). For these authors, recent technological change results in a large automation of "middle education" routine tasks. The computerization of these jobs put "middle education" workers out of employment. They then accept service occupation jobs that are expensive and cumbersome to computerize. We identify routine occupations in the list of our 537 jobs. Appendix 7 provides the list of routine jobs. We expect a positive estimated coefficient.

- change in unemployment rate ($du_{i,t} = u_{i,t} - u_{i,t-1}$) measures the job reallocation between service occupations and other sectors [10]. We then expect a positive estimated sign on this variable.

- change in female active labor force ($dfemale_{i,t} = \frac{N_{it}^{female}}{N_{it}^{female}+U_{it}^{female}} - \frac{N_{it-1}^{female}}{N_{it-1}^{female}+U_{it-1}^{female}}$). This captures demand driven shift in service occupation. With more women on the labor market, we expect an increase in the demand for service occupation.

- the change in the share of manufacturing jobs in total employment ($dmanuf_{i,t} = \frac{N_{i,t}^{manuf}}{N_{i,t}} - \frac{N_{i,t-1}^{manuf}}{N_{i,t-1}}$) controls for a composition effect. If manufacturing expands in region i, less workers become available for service occupations. The estimated coefficient on $dmanuf_{i,t}$ would then be negative.

All control variables are computed using French LFS, except *old* and u, that are taken from the French Institute of Statistics database (INSEE).

Table 2 reports estimated results on the regional panel data and indicates a significant positive relationship between aging and growth in service employment. Autor and Dorn (2010) also found that a growing share of senior citizens is predictive of growth in service employment. However, in Autor and Dorn (2010), aging is just another control variable, introduced in first-difference. In this paper, we are more careful about measuring this effect by introducing the variable in level and with a lag, thereby ensuring its exogeneity.

This finding is robust to the inclusion of control variables as well as time and region-specific dummies[11]. Furthermore, in order to ensure that we are not merely computing an income effect, in column 2 we implement the regression controlling for the variation in the regional GDP per capita. In both columns control variables display the expected sign. In particular, the change in the share of routine employment appears with a significant and positive sign. Regions that specialize in routine

[10] This variable could also capture the average level of income that can be spent on service activities such as gardeners, house cleaners or child care, in which case the estimated coefficient associated with du_{it} would be negative.

[11] Regressions available upon demand.

tasks activities experience the following year a rapid growth in service employment, which extends Autor and Dorn (2010)'s findings to French data. Unemployment variation, the variation in the female active labor force and the variation in the regional GDP per capita positively contribute to the increase in the share of service employment. The larger the increase in the share of workers employed in the manufacture sector, the lower the share of workers reallocated to the personnel service sector. Finally, the variance inflation factor (VIF) reveals the presence of a multicollinearity problem[12]. This can affect the stability of the estimated coefficients, since multicollinearity tends to enlarge standard errors. In the following subsections we test thus the robustness of these results.

2.2.1 The endogeneity problem

Evidently, our regressions display an endogeneity problem, that is, the share of workers employed in the personnel service sector of region i may increase because the share of old retired individuals (who asks for these services) living in that region increases or we can think the other way round and argue that old people move to regions where the supply of personnel services follows a rising path. In order to deal with this problem, the first column of table 3 regresses the change in the share of workers employed in the personnel service sector in region i over the share of old workers in region i that were born in region i. This permits to control for the potential endogeneity problem coming from old workers moving to regions where the supply of personnel service is larger. Being born in a region, represents an exogenous reason justifying the old worker's residence choice.
Results in the first column confirm the findings of our benchmark regression. The share of old workers in region i born in region i displays a significant and positif coefficient. Again, a large the share of old workers in a particular region, pushes up the share of workers employed in personnel services in that region. The share of people employed in routine positions continues to have a positive influence, as well as the variation in the unemployment rate and the female workforce. The change in the employment share of the manufacture sector keeps its negative sign.

2.2.2 The interaction between aging a the share of labor input in routine jobs

According to our estimations, population aging seems to be one of the factors behind the demand shift towards the personnel service sector. However, it is not the only one. As shown in table 2 and in the first column of table 3, the share of workers employed in routine positions plays a major role in explaining the increase in the share of personnel service jobs. This is consistent with previous results in the literature, which claims that the diffusion of new technologies has allowed to

[12]Multicollinearity disappears as soon as we eliminate from the regression the time and regional dummies.

Table 2: Change in service employment share and aging : Benchmark regression at the regional level (1993-2007)

Variables	Benchmark	
$old_{i,t-1}$	0.0691***	0.0839***
	(0.000175)	(0.000174)
$routine_{i,t-1}$	0.223***	0.230***
	(0.000110)	(0.000111)
$dpib_{i,t}$		0.0379***
		(3.74e-05)
$du_{i,t}$	0.239***	0.277***
	(0.000128)	(0.000134)
$dfem_{i,t}$	0.0821***	0.0852***
	(3.31e-05)	(3.28e-05)
$dmanuf_{i,t}$	-0.126***	-0.123***
	(2.37e-05)	(2.36e-05)
Time dummies	Yes	Yes
Regional dummies	Yes	Yes
Observations	288	288
R-squared	0.150	0.152
VIF	20.63	20.56

Standard errors in parentheses

$***p<0.01, **p<0.05, *p<0.1$

Table 3: Change in service employment share and aging : old people born in the same region where they live and the interacted role of aging and routine jobs. Regions 1993-2007.

Variables	Dependent variable: Δperonnel service employment		
$(old\ born\ in\ the\ region)_{i,t-1}$	0.00886***		
	(7.24e-06)		
$routine_{i,t-1}$	0.228***	0.218***	-0.610***
	(0.000113)	(0.000112)	(0.000694)
$old \cdot routine_{i,t-1}$			3.895***
			(0.00332)
Control variables	Yes	Yes	Yes
Time dummies	Yes	Yes	Yes
Regional dummies	Yes	Yes	Yes
Observations	288	288	288
R-squared	0.152	0.150	0.152

Standard errors in parentheses

$***p<0.01, **p<0.05, *p<0.1$

Control variables:$du_{i,t}$, $dfem_{i,t}$, $dmanuf_{i,t}$

replace labor input in routine tasks by computers, and part of this workforce has been reallocated towards jobs at the bottom of the wage distribution (see Goos and Maning (2007), Autor, Levy, and Kearney (2006) or Autor and Dorn (2010)). In the second column of table 3 we eliminate the share of old retired workers as explanatory variable. We simply regress the change in the share of employment in the personnel service sector over the share of people employed in routine tasks, controlling for the variation in unemployment, in female active labor force and in the share of employment in the manufacturing sector. Results are perfectly in line with the existing literature, since the coefficient associated with the variable $routine_{i,t-1}$ is clearly positive and significant, suggesting that the larger the share of workers employed in routine positions the larger the increase in the employment share of personnel services.

However, it is not because there is a large mass of workers replaced by computers that the demand for workers at the bottom of the wage distribution is going to increase. We need to combine this

labor supply shock (increase in the share of workers searching for a new job since they have been replaced by computers in their previous job) with a labor demand shock fostering an increase in the demand for labor in low paid jobs. Our claim is that the labor demand shock is induced by population aging, since old people require more personnel services. Combining the progressive substitution of labor in routine tasks by machines with population aging should explain the rise in the employment share in the personnel service sector. The third column of table 3 exploits this idea. We implement our standard regression introducing as explanatory variable the share of people employed in routine tasks and an interacted term resulting from multiplying the shares of old retired people and workers employed in routine tasks. Results are very interesting. Whereas control variables keep their expected sign, the coefficient associated with the individual variable $routine_{i,t-1}$ becomes negative and significant and that associated with the interacted term is positive, significant and relatively large. Our estimations suggest then, that the rise in the share of employment in the personnel service sector comes from the combined effect of an increasing share of workers made available in the market since they have been replaced by machines in their previous jobs and an increasing share of old workers. Once this interacted effect is controlled, the individual impact of the share of workers in routine tasks becomes negative since it probably captures a composition effect.

2.2.3 The income power

As found in the previous subsection the diffusion of new technologies has allowed to replace labor input in routine tasks by computers. Part of this workforce seems to have been reallocated towards jobs at the bottom of the wage distribution which has permitted to satisfy an increasing demand for personnel services. The main claim of this paper is that one of the main factors behind the increased demand for services is population aging. Old people require the assistance provided by personnel workers, however, they require income power to pay for these services.

Columns 1 and 2 of table 4 regress the variation in personnel service employment at date t over the share of old retired people that in $t-1$ used to be employed in executive occupations and in manual workers occupations, respectively. We control for the share of workers in routine positions in $t-1$, as well as for the variation in unemployment, female active labor force and manufacture employment. Results are clear cut. Whereas the share of executive (rich) old people positively influences the increase in the share of people employed in personnel services, the share of manual workers (poor) old people negatively influences it. In sum, the positive impact of population aging over the share of employment in the service sector estimated in table 2 can only hold if, at the

Table 4: Change in service employment share and aging : rich old people *vs.* poor old people. Regions 1993-2007.

Variables	Dependent variable: Δperonnel service employment	
$Rich\ old_{i,t-1}$	0.0292***	
	(3.76e-05)	
$Poor\ old_{i,t-1}$		-0.00639***
		(1.83e-05)
$routine_{i,t-1}$	0.214***	0.217***
	(0.000111)	(0.000112)
Control variables	Yes	Yes
Time dummies	Yes	Yes
Regional dummies	Yes	Yes
Observations	288	288
R-squared	0.151	0.150

Standard errors in parentheses

$***p<0.01, **p<0.05, *p<0.1$

Control variables:$du_{i,t}$, $dfem_{i,t}$, $dmanuf_{i,t}$

aggregate level, the average income power of old people does not fall. Weakly paid old people cannot afford personnel services.

2.2.4 The relationship between aging and service activities

In Table 5, we investigate whether the link between our demand-driven effect is pervasive among service activities. Service occupations are broken down into 7 broad categories. Appendix 7 provides the list of jobs corresponding to each category. The positive link between aging and growth in service employment appears robust for all service activities except child care. This confirms our interpretation of aging as a demand effect. Individuals aged 60+ do not hire nannies[13], therefore we do not find a significant positive sign of aging on child care. The effect of aging on growth of service employment is particularly strong on housing and recreational activities. Control variables

[13]Even though grand parents can substitute for nannies.

Table 5: Change in service employment share and aging : Detailed service occupation. Regions 1993-2007

VARIABLES	Misc.	Beauty	Health	Child care	Janitor	House	Recreation
$old_{i,t-1}$	0.000486***	0.0400***	0.0287***	-0.134***	0.0311***	0.0450***	0.0575***
	(2.32e-05)	(5.98e-05)	(9.15e-05)	(0.000110)	(3.68e-05)	(8.67e-05)	(8.83e-05)
$routine_{i,t-1}$	-0.0181***	0.110***	0.0340***	0.0538***	0.0214***	0.0507***	-0.0288***
	(1.53e-05)	(3.41e-05)	(5.74e-05)	(5.65e-05)	(2.78e-05)	(5.20e-05)	(6.06e-05)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regional dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	288	288	288	288	288	288	288
R-squared	0.068	0.091	0.053	0.155	0.150	0.133	0.112

Standard errors in parentheses

$***p<0.01, **p<0.05, *p<0.1$

Control variables:$du_{i,t}$, $dfem_{i,t}$, $dmanuf_{i,t}$

have different effects depending on the service activity we consider. Whereas $routine_{i,t-1}$ keeps a positive impact for beauty, health, child care, janitor and housing services, it displays a negative impact for miscellaneous and recreation service, suggesting that workers replaced by machines do not reallocate themselves in miscellaneous or recreational services.

2.2.5 The geographical level

Finally, we check the robustness of the aging effect by considering smaller geographical units (95 departments versus 21 regions in previous tables). As previously, our sample spans 1993-2007, which yields a panel data of 1304 observations. Using the department level allows us to consider a larger sample. In addition, the empirical exercise will measure whether the relationship is pervasive over smaller geographical units. Table 6 reports the estimated coefficients. Since the unemployment variable captures a job reallocation effect, we use the unemployment rate at the regional level. Estimates confirm the robustness of our demand driven effect associated with aging. The positive coefficient on the share of old retired citizens is robust to the introduction of department-specific dummies and time dummies (compare the two first columns). In addition, the estimated coefficient

on $old_{i,t-1}$ is not affected if we consider the change in unemployment rate at the department level rather than the regional level. In both cases it keeps the positive and significant coefficient.
Columns 3, 4 and 5 of table 6 repeat the same robustness tests we implemented for regions. In column 3, we replace the share of old retired workers living in a given department by the share of old retired workers that live in the same department as they were born. Our estimations confirm the previous result for regions, the larger the share of old workers the larger the increase in the share of service employment. Columns 4 and 5, allow us to draw two conclusions. On the one hand, column 4 shows that when the share of old workers is removed from the regression, the potential replacement of labor input in routine tasks by computers fosters an increase in the share of service employment. If we combine this substitution process with population aging in an interacted term, $old \cdot routine_{i,t-1}$, we realize that the positive impact on the employment share of the service sector, is mainly explained by this interacted variable, and that the potential replacement of labor input by machines does not longer have a positive influence on the employment share in personnel service. This result was exactly the same when we were considering regions.
The empirical investigation confirms that the French labor market has experienced a job polarization, with a rapid employment growth at the bottom and top end of the wage distribution. The data suggests that personal service occupations drive the rise in "lousy jobs". Our regressions also indicate that the rise in personal service occupations is linked to ICT, as in Autor and Dorn (2010), but also to aging. Actually, it seems to be the combined effect of new technologies replacing labor input in routine tasks and population aging that explains job polarization in the service sector. We interpret our estimates as suggestive that the rise in personal service jobs is also driven by the rising demand from older people.

2.3 Growth in wage inequality and aging

The rise in "lousy jobs" jobs has been associated with an increase in the growth rate of the wage earned by this type of jobs in countries like the US of UK (see Autor and Dorn (2010) or Goos and Maning (2007)). Even if, as noted by Goos, Maning, and Salomons (2010), in many European countries, and particularly in France, the presence of labor market institutions may prevent a large wage response, Figure 3 (average change in log hourly wage) suggests that the largest wage rises have occurred for jobs located at the bottom of the wage distribution at the beginning of the job polarization process (beginning of the nineties). This result holds when we correct for the growth rate of the minimum wage (panel (ii)). Moreover, panel (d) of Table 1 suggests that service occupation jobs have been characterized by a significant rise in wage over the 1993-2007 period.

Table 6: Change in service employment share and aging : Department level (1993-2007)

VARIABLES	Benchmark				
$old_{i,t-1}$	0.0314***	0.0138***			
	(0.000248)	(2.61e-05)			
$routine_{i,t-1}$	0.296***	0.243***	0.297***	0.295***	-0.633***
	(0.000264)	(0.000214)	(0.000261)	(0.000261)	(0.000755)
$(old\ born\ in\ the\ region)_{i,t-1}$			0.00799***		
			(1.99e-05)		
$old \cdot routine_{i,t-1}$					4.136***
					(0.00411)
Control variables	Yes	Yes	Yes	Yes	Yes
Time dummies	Yes	No	Yes	Yes	Yes
Department dummies	Yes	No	Yes	Yes	Yes
Observations	1304	1304	1304	1304	1304
R-squared	0.320	0.302	0.320	0.320	0.322

Standard errors in parentheses

$***p<0.01, **p<0.05, *p<0.1$

Control variables:$du_{i,t}$, $dfem_{i,t}$, $dmanuf_{i,t}$

(i): Benchmark (ii): Corrected for the growth rate of w_{min}

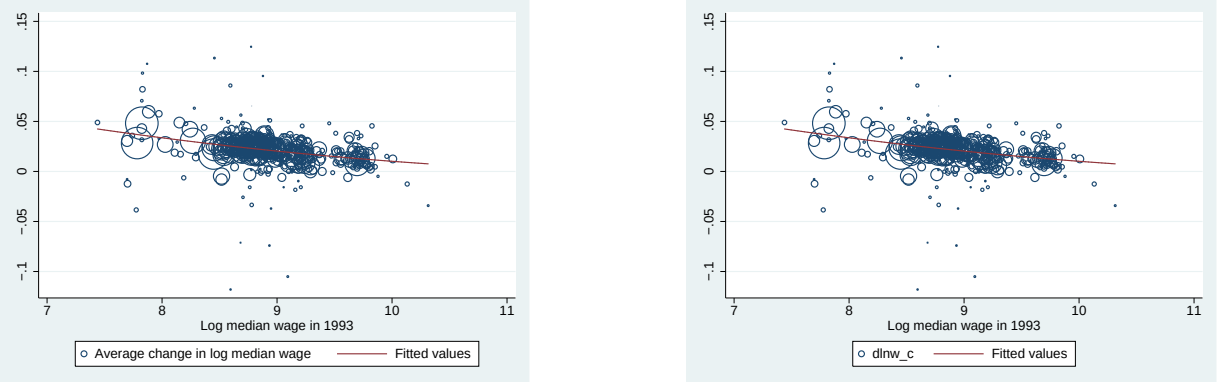


Figure 3: Average wage growth for men and women by job median wage. . Regions 1993-2007..

We estimate separately the following equations

$$d\left(\frac{P50}{P10}\right) = \alpha + \beta\ old_{i,t-l} + \gamma X_{i,t} + e_{i,t}$$
$$d\left(\frac{w_{ns}}{w_s}\right) = \alpha + \beta\ old_{i,t-l} + \gamma X_{i,t} + e_{i,t}$$

where $d\left(\frac{P50}{P10}\right)$ denotes the change in wage inequality measured as the ratio between the fifth and the first decile and $d\left(\frac{w_{ns}}{w_s}\right)$ corresponds to the change in the ratio between the average wage earned in non service sectors and the average wage earned in service sectors.

Our paper explores the view that the rise in service employment and wage is demand driven, in particular, by aging individuals. This effect is measured here again by the share of individuals aged 60 and more in the total population. This share is lagged. If our hypothesis is confirmed by the data, we expect $\beta < 0$, since the increased demand of services coming from old consumers should tend to increase wages associated to these jobs and then reduce wage inequality between service and non service sector and between the fifth and the first decile.

$X_{i,t}$ denotes a set of control variables that include: lagged share of routine jobs (ratio of the number of employed individuals in routine jobs to total employment in region i and year $t-l$), change in unemployment rate, change in female active labor force, change in the share of manufacturing jobs in total employment, time dummies and regional dummies.

We work with our regional database. Estimations in table 7 reveal that both, the population aging together with the routinization process contribute to a reduction in wage inequality between the middle and the bottom of the distribution, suggesting a faster rise of wages in the first decile. This result is confirmed if instead of distinguishing between deciles in the distribution, we deal with non service and service jobs. Note though that, when dealing with wages, we are obliged to

Table 7: Wage inequality and aging. Regions 1993-2007.

VARIABLES	change in P50/P10	change in w_{ns}/w_s
$old_{i,t-5}$	-0.224***	
	(0.000160)	
$routine_{i,t-1}$	-0.120***	
	(8.68e-05)	
$old_{i,t-2}$		-0.359***
		(0.000309)
$routine_{i,t-3}$		-0.143***
		(0.000201)
Control variables	Yes	Yes
Time dummies	Yes	Yes
Regional dummies	Yes	Yes
Observations	204	243
R-squared	0.376	0.086

Standard errors in parentheses

$***p<0.01, **p<0.05, *p<0.1$

Control variables:$du_{i,t}$, $dfem_{i,t}$, $dmanuf_{i,t}$

introduce higher lags in both the old_{t-l} variable and the $routine_{t-l}$ variable than when dealing with employment in order to find a significant impact on wage inequalities. The presence of rigid institutions on the French labor market probably explains the slow reaction of wages to population aging and to routinazation.

In sum, the reduction in wage inequality can be claimed to be demand driven, even if the diffusion of new technologies has certainly contributed too by decreasing the wage growth of middling occupations. Next section aims at shedding light on the economic mechanisms behind the interaction between ICT and aging.

3 The interaction between ICT and aging : A theoretical analysis

We analyze how the interaction between ICT and aging can generate an increase in service employment, that can explain the progressive polarization of employment towards the bottom of the distribution. Our theoretical model draws on Autor and Dorn (2010)'s framework. We present in appendix a simplified Autor and Dorn (2010)'s setting by considering only a two-input model (versus a 3-input model in Autor and Dorn (2010)) in order to show that a two-input model is enough to shed light on the economic mechanisms operating behind the polarization of employment towards the bottom of the distribution.

In this section we amend Autor and Dorn (2010)'s framework to introduce aging by distinguishing between two groups of individuals, young people that work and old people that are retired. For sake of simplicity, we abstract from savings and assume that retirees' income (the retirement pension, *pens*) comes from a PAYG system funded by a tax on wages (τ). To keep an analytically tractable framework, we assume no transitions between both groups. The only source of difference between them are preferences, and more precisely, the degree of substitutability between goods and services. Whereas young workers can specialize their consumption bundle on goods if they become relatively less expensive, old individuals need to diversify their consumption bundle between goods and services. The idea is simple, if apples become relatively less expensive than home services, young workers may replace services by apples. In contrast, old individuals need always home services to help them to clean the house or to eat the apples, so even if apples become relatively less expensive, seniors keep consuming services.

On the production side, we assume two perfectly competitive sectors. The good sector, employing labor and capital to produce a final good, and the service sector, employing only labor. We assume that labor and capital inputs in the good sector are substitutes which allows us to reproduce the decrease in the relative price of goods following the diffusion of ICT. More precisely, we can think about the good sector as an industrial sector where the output is produced employing uniquely routine labor and capital. Then, if the price of capital falls, firms replace labor by capital, which allows to reduce production costs.

To capture the observed increase in wage inequality between the service and the good sector we consider heterogeneous workers in terms of skills. There is a continuum of mass M_1 of workers, each of whom is endowed with a given skill level $\eta \in [0, 1]$ and supplies labor either in the service sector or in the good sector. We assume that the least qualified workers are employed in the service

sector whereas those that are slightly more qualified go to the good sector. More precisely, we assume that workers with an $\eta \in [0, \eta^*]$ are employed in the service sector whereas workers with an $\eta \in [\eta^*, 1]$ are employed in the good sector. η^* will be endogenously determined at the general equilibrium.

Workers have homogeneous skills at performing services' tasks whereas they have heterogeneous skills in performing tasks in the good sector. This hypothesis is required if we want workers in the good and service sector to have different wages. Let η denote the worker's skill measured in efficiency units in the good sector, with density and distribution functions $f(\eta)$ and $F(\eta)$. There is a mass equal to one of potential good-sector labor input in efficiency units: $\int \eta f(\eta) d\eta = 1$. It is convenient to choose a functional form for $f(\eta)$ to permit analytic solutions of the model. Let η be distributed uniformly on the interval [0,1] with $f(\eta) = \frac{1}{1-0}$ for all η within the interval [0,1].

Each worker supplies labor inelastically to the task offering the highest income level given her endowment, η. Denoting $w_s(t)$ and $w_r(t)$ the wage in the service and the good sector, respectively, all labor will be employed in the service sector if $w_s(t) > w_r(t)\eta*$, whereas for $w_s(t) < w_r(t)\eta*$ all labor will go to the good sector.

3.1 Good-producing sector

Production goods combine routine labor, measured in efficiency units, and capital using the following technology:

$$\Pi^g = \max \{Y^g(t) - p_k(t)K(t) - w_r(t)L_{g_e}(t)\}$$

$$\text{s.t.} \qquad F(K(t), L_{g_e}(t)) \leq Y^g(t)$$
$$L_{g_e} = \int_{\eta*}^{1} \eta d\eta = \frac{\eta^2}{2} = \frac{1}{2} - \frac{\eta^{*2}}{2}$$

with Y^g the output in the good sector, K capital, L_{g_e} unskilled labor in efficiency units, p_k the real price of capital and w_r the real wage.

Firms maximize profits taking the price of consumption goods and wages as given. The CRS technology ensures that equilibrium profits will be zero. The FOCs are:

$$K \quad : \quad F'_K(K(t), L_{g_e}(t)) = p_k(t)$$
$$L \quad : \quad F'_{L_{g_e}}(K(t), L_{g_e}(t)) = w_r(t)$$

FOCs can be rewritten as

$$f'(k(t)) = p_k(t)$$
$$f(k(t)) - k(t)f'(k(t)) = w_r(t)$$

with $k(t) = K(t)/L_{g_e}(t)$.

3.2 Service-producing sector

Again, firms maximize profits taking the price of services and wages as given. The service-producing sector uses only manual labor, measured in efficiency units. The firm's optimizing problem equals:

$$\Pi^s = \max \{p(t)Y^s(t) - w(t)L_{s_e}(t)\}$$

$$\text{s.t.} \qquad \alpha_s L_s \leq Y^s(t)$$
$$L_{s_e} = \int_0^{\eta^*} d\eta = \eta^* \tag{1}$$

where L_{s_e} represents labor input in efficiency units and $p(t) = \frac{p_s}{p_g}$, so that all the production side is expressed in units of goods. The labor demand in the service sector is such that

$$p(t)\alpha_s = w(t)$$

3.3 The supply side equilibrium: input ratio and prices.

The equilibrium is defined by a set of 6 equations:

$$f'(k(t)) = p_k(t) \tag{2}$$
$$f(k(t)) - k(t)f'(k(t)) = w_r(t) \tag{3}$$
$$p(t)\alpha_s = w_s(t) \tag{4}$$
$$\eta^* = \frac{w_s(t)}{w_r(t)} \tag{5}$$
$$L_{s_e} = \eta^* \tag{6}$$
$$L_{g_e} = \frac{1}{2} - \frac{\eta^{*2}}{2} \tag{7}$$

There are 6 explicit[14] unknown variables: $k(t)$, $w_r(t)$, $w_s(t)$, $\eta^* = L_{s_e}$, L_{g_e} and p.

Under the hypothesis of substitutability between routine labor and capital in the good sector, a decrease in the price of capital should induce a progressive substitution of labor by capital since capital becomes relative less expensive. The relative price of services with respect to goods increases, which should favor a rise in the service's wage. We might think that labor would be directly allocated to the service sector, however, the decline in the relative price of goods, can foster a rise in the relative demand of goods if goods and services are substitutes in the agent's preferences. Only when goods and services are complementary, we are likely to observe a simultaneous increase

[14]There are 2 implicit unknowns Y_g and Y_s. Both are determined by the respective production functions.

in the demands for goods and services following the rise in $p(t)$. Demand forces may then go against supply forces. The demand side is thus required to determine the equilibrium.

3.4 Preferences and consumption choices.

Consumers take prices and wages as given and maximize utility subject to the budget constraint that consumption equals income. We consider the following CES utility functions:

$$\begin{aligned}\mathcal{U}_1 &= C_1 = \left[\nu_1 C_{1,g}^{\rho_1} + (1-\nu_1) C_{1,s}^{\rho_1}\right]^{\frac{1}{\rho_1}} \\ \mathcal{U}_2 &= C_2 = \left[\nu_2 C_{2,g}^{\rho_2} + (1-\nu_2) C_{2,s}^{\rho_2}\right]^{\frac{1}{\rho_2}}\end{aligned}$$

The young (type 1) and the old (type 2) agents do not have the same preferences. More specifically, we assume that the elasticity of substitution between good and services decreases with age. This hypothesis is consistent with empirical findings on age-dependent consumption patterns (UN (2007)) and estimates of age-related elasticities of substitution (Luhrmann (2008)).
This shift in preferences with the agent's age allows us to explain how the dynamics of the population composition can affect the impact of ICT diffusion on the size of the service sector.
Type-1 agents, young workers, produce whereas type-2 agents, the retirees, receive a pension. The income levels are then defined by:

$$I_1 = (1-\tau)(w_r L_{g_e} + w_s L_{s_e}) \quad \text{and} \quad I_2 = pens$$

The young population earns a wage that is taxed to fund retirement pensions, and the old population receives the retirement pension. The presence of young workers is then necessary in the economy since otherwise there is no production and no pension can be paid to old individuals. We assume that there is a mass M_1 of type-1 agents and a mass M_2 of type-2 agents. The budget constraint of the PAYG system is

$$M_1 \tau (w_r L_{g_e} + w_s L_{s_e}) = M_2 pens$$

For $i = 1, 2$, we can write the optimizing problem as follows:

$$\max_{C_i, C_{i,s}, C_{i,g}} \{C_i\}$$

$$\text{s.t.} \qquad p_i C_i = p_s C_{i,s} + p_g C_{i,g}, \tag{8}$$

$$\tag{9}$$

which yields the following FOC:

$$1 - \lambda p_i = 0 \Rightarrow \lambda = \frac{1}{p_i} \tag{10}$$

$$\frac{\partial C_i}{\partial C_{i,s}} - \lambda p_s = 0 \Rightarrow \left[\nu_i C_{i,g}^{\rho_i} + (1-\nu_i) C_{i,s}^{\rho_i}\right]^{\frac{1-\rho_i}{\rho_i}} (1-\nu_i) C_{i,s}^{\rho_i - 1} = \lambda p_s \tag{11}$$

$$\frac{\partial C_i}{\partial C_{i,g}} - \lambda p_g = 0 \Rightarrow \left[\nu_i C_{i,g}^{\rho_i} + (1-\nu_i) C_{i,s}^{\rho_i}\right]^{\frac{1-\rho_i}{\rho_i}} \nu_i C_{i,g}^{\rho_i - 1} = \lambda p_g \tag{12}$$

$$\tag{13}$$

Because $C_i^{\rho_i} = \left[\nu_i C_{i,g}^{\rho_i} + (1-\nu_i) C_{i,s}^{\rho_i}\right]$, we can rewrite (11) as follows:

$$[C_i^{\rho_i}]^{\frac{1-\rho_i}{\rho_i}} (1-\nu_i)(C_{i,s})^{\rho_i - 1} = \frac{p_s}{p_i}, \quad \text{which yields}$$

$$C_{i,s} = \left(\frac{p_s}{p_i}\right)^{\frac{1}{\rho_i - 1}} \left(\frac{1}{1-\nu_i}\right)^{\frac{1}{\rho_i - 1}} C_i \tag{14}$$

Applying the same reasoning to equation (12) leads to:

$$C_{i,g} = \left(\frac{p_g}{p_i}\right)^{\frac{1}{\rho_i - 1}} \left(\frac{1}{\nu_i}\right)^{\frac{1}{\rho_i - 1}} C_i \tag{15}$$

Equations (14) and (15) can now be replaced in the budget constraint (8) so as to obtain the expression for the price index:

$$p_i = \left[(1-\nu_i)^{\frac{1}{1-\rho_i}} p_s^{\frac{\rho_i}{\rho_i - 1}} + \nu_i^{\frac{1}{1-\rho_i}} p_g^{\frac{\rho_i}{\rho_i - 1}}\right]^{\frac{\rho_i}{\rho_i - 1}} \tag{16}$$

$$\frac{p_i}{p_g} = \left[(1-\nu_i)^{\frac{1}{1-\rho_i}} \left(\frac{p_s}{p_g}\right)^{\frac{\rho_i}{\rho_i - 1}} + \nu_i^{\frac{1}{1-\rho_i}}\right]^{\frac{\rho_i}{\rho_i - 1}} \tag{17}$$

3.5 The equilibrium

Because we consider two types of individuals having different utility functions, representing the central planer problem as in Autor and Dorn (2010) can become a complicated task. Essentially, the problem is to decide about the form of the welfare function. Should the central planer give an identical weight to both populations? Should the weight be rather proportional to the size of the population? This leads us to focus on the decentralized problem. On the demand side we have 6

unknown variables: $p = \frac{p_s}{p_g}$, $\gamma_s = \frac{p_s}{p_i}$, $\gamma_g = \frac{p_g}{p_i}$, $\Gamma = \frac{p_1}{p_2}$, C_1 and C_2. There are also 6 equations:

$$p = \frac{\gamma_s}{\gamma_g} \tag{18}$$

$$\begin{aligned} Y_s &= C_{1,s} + C_{2,s} = M_1 \gamma_s^{\frac{1}{\rho_1 - 1}} \left(\frac{1}{1-\nu_1}\right)^{\frac{1}{\rho_1 - 1}} C_1 \\ &\quad + M_2 (\gamma_s \Gamma)^{\frac{1}{\rho_2 - 1}} \left(\frac{1}{1-\nu_2}\right)^{\frac{1}{\rho_2 - 1}} C_2 \end{aligned} \tag{19}$$

$$\begin{aligned} Y_g &= C_{1,g} + C_{2,g} = M_1 \gamma_g^{\frac{1}{\rho_1 - 1}} \left(\frac{1}{\nu_1}\right)^{\frac{1}{\rho_1 - 1}} C_1 \\ &\quad + M_2 (\gamma_g \Gamma)^{\frac{1}{\rho_2 - 1}} \left(\frac{1}{\nu_2}\right)^{\frac{1}{\rho_2 - 1}} C_2 \end{aligned} \tag{20}$$

$$p_1 C_1 = (1-\tau)(w_r L_{ge} + w_s L_{se}) p_g \Rightarrow C_1 = \gamma_g (1-\tau)(w_r L_{ge} + w_s L_{se}) \tag{21}$$

$$p_2 C_2 = pens \cdot p_g \Rightarrow C_2 = \gamma_g \tau (w_r L_{ge} + w_s L_{se}) \frac{M_1}{M_2} \tag{22}$$

$$\Gamma = \frac{p_1}{p_2} = \frac{\frac{p_1}{p_g}}{\frac{p_2}{p_g}} = \frac{\left[(1-\nu_1)^{\frac{1}{1-\rho_1}} \left(\frac{p_s}{p_g}\right)^{\frac{\rho_1}{\rho_1 - 1}} + \nu_1^{\frac{1}{1-\rho_1}}\right]^{\frac{\rho_1}{\rho_1 - 1}}}{\left[(1-\nu_2)^{\frac{1}{1-\rho_2}} \left(\frac{p_s}{p_g}\right)^{\frac{\rho_2}{\rho_2 - 1}} + \nu_2^{\frac{1}{1-\rho_2}}\right]^{\frac{1-\rho_2}{\rho_2}}} \tag{23}$$

The complexity of the system prevents us from providing analytical solutions. However, the numerical simulations presented in the following section confirm our intuition: under the hypothesis that capital and labor are substitutes in the production function and that goods and services are more complementary for old individuals than for young workers, aging of the population combined with technological diffusion yields a progressive polarization of labor into the service sector. More precisely, the diffusion of ICT induces a decrease in the price of capital that promotes the substitution of labor input in the good sector by capital (relatively less expensive factor). As a result, the relative price of goods falls, which should stimulate its demand. If, for a (growing) proportion of the total population, goods and services are complementary, the increase in the demand for goods will also be associated with an increase in the demand of services. Because goods are mostly produced with capital, labor should reallocate to the service sector, which requires an increasing number of workers to satisfy the newly created demand.

4 Numerical simulations

This section proposes numerical experiments in order to test the ability of the model to reproduce employment polarization at the bottom of the job quality distribution (personnel services) when new technologies are diffused in a context of population aging. These experiments contribute then to enriching the discussion about the sources underlying behind the observed change in the structure

Table 8: Baseline parameter values.

Elasticity of substitution between capital and labor	$\mu = 0.5$
Elasticity of substitution between goods and services	$\rho_1 = 0.5$ | $\rho_2 = -0.5$
Marginal productivity service sector	$\alpha_s = 1$
Weight of capital in the production process	$\lambda = 1/3$
Weight of goods in the utility function	$\nu_1 = 0.6$ | $\nu_2 = 0.4$

of employment, which has become concentrated on good and bad jobs.

The results reported in this section are based on the following additional assumptions. The diffusion of new technologies is represented by a decreasing sequence in the price of capital (as in Autor and Dorn (2010) p_k is assumed to converge towards zero). We represent population aging between 1990 and 2010 using data provided by the French National Statistics Institute concerning the proportion of people aged more than 60 years old in France. More precisely, in 1990 people below 60 years old represented 75% of the population whereas in 2010 this proportion had fallen to 68%. To keep as close as possible to the French PAYG system, we consider that old people income power must not fall along time. Because the proportion of working population has decreased between 1990 and 2010, this implies that the tax rate paid by young to finance the pension system must increase (we consider a 10 percentage point increase [15]) to leave retirement pensions unaffected by the demographic progression.

The baseline parameters used in computations are shown in Table 8. We adopt the standard parameter values in the literature. More precisely, we consider a value of λ in the CES production function of the good sector equal to 1/3 for capital. Concerning the elasticity of substitution between both input factors, we require them to be substitutes so that the decrease in the relative price of capital fosters a progressive substitution of labor by capital ($\mu = 0.5$). Concerning the service sector, we follow Autor and Dorn (2010) and impose a marginal productivity of labor equal to unity ($\alpha_s = 1$).

The utility function of young and old people differ. In the consumption bundle of young workers, the presence of goods is relatively more important ($\nu_1 = 0.6$), whereas old people give a more important weight to the consumption of services ($\nu_2 = 0.4$). Elasticities of substitution between goods and services also vary with the worker's age. Whereas for young workers goods and services are rather substitutes (ρ_1 must be defined between 0 and 1), for old people they are complements

[15] In the report of the COR (2001), a 10 percentage point increase in the contribution rate would be enough to balance the predicted Social Security budget.

(ρ_2 should be negative). This corresponds well to the findings of UN (2007) and Luhrmann (2008). For sake of simplicity, we impose $\rho_1 = 0.5$ and $\rho_2 = -0.5$.

Macroeconomic effects of a fall in the price of capital

Figure 4 reports the macroeconomic effects of a fall in the price of capital p_K, which entices the firm to substitute labor for capital (given the calibration of the production function). There is then a rise in the capital-to-labor ratio k and a decline in labor, L_{g_e}. Since the firm substitutes labor for capital whose price is falling, it can produce at a cheaper cost. As a result, the price of goods goes down while the production of goods Y_g expands.

The fall in the price of goods entices young consumers (which represent 75% of the population) to favor goods (since goods and services are substitutes in their consumption basket). In contrast, old consumers (25% of the population) increase their demand for goods and services (since goods and services are complements in their consumption basket). Production of goods is then encouraged. The demand for services also increases, driving up the relative price of services $p = \frac{p_s}{p_g}$ and the production in the service sector. Because the only input of production in the service sector is labor, the demand for labor in this sector rises and so do wages, w_s. The measure of wage inequality between both sectors $\eta^* = \frac{w_s}{w_r}$ goes up.

Figure 4 corresponds well to results displayed in column 2 of table 3, where we remark that, during the 1993-2007 period, the larger the share of workers employed in routine tasks the larger the increase in the share of workers employed in personnel services. Because the relative price of capital fell during this period, our estimations suggest that the larger the proportion of workers employed in programmable (routine) positions the larger the potential replacement of workers by machines. These workers can then be reallocated towards other sectors.

The impact of aging

Figure 5 reports the macroeconomic effects of the same reduction in the relative price of capital considered in the benchmark calibration but in the presence of an aging economy. As already stated, the progression in the proportion of young workers in the economy is calibrated so as to mimic the estimated values by the French National Statistical Institute (M_1 evolves from 75% to 68%). The pay-as-you-go pension system is then funded through a 10 percentage point increase in the contribution rate τ. This rise of the contribution rate is necessary if we want old consumers to keep their income constant in a context where the size of the working population (young people) is falling.

The impact of the aging economy mainly lies in the service sector. We can clearly deduce from equations (2) and (3), the impact of the technological diffusion process on the capital-to-labor ratio,

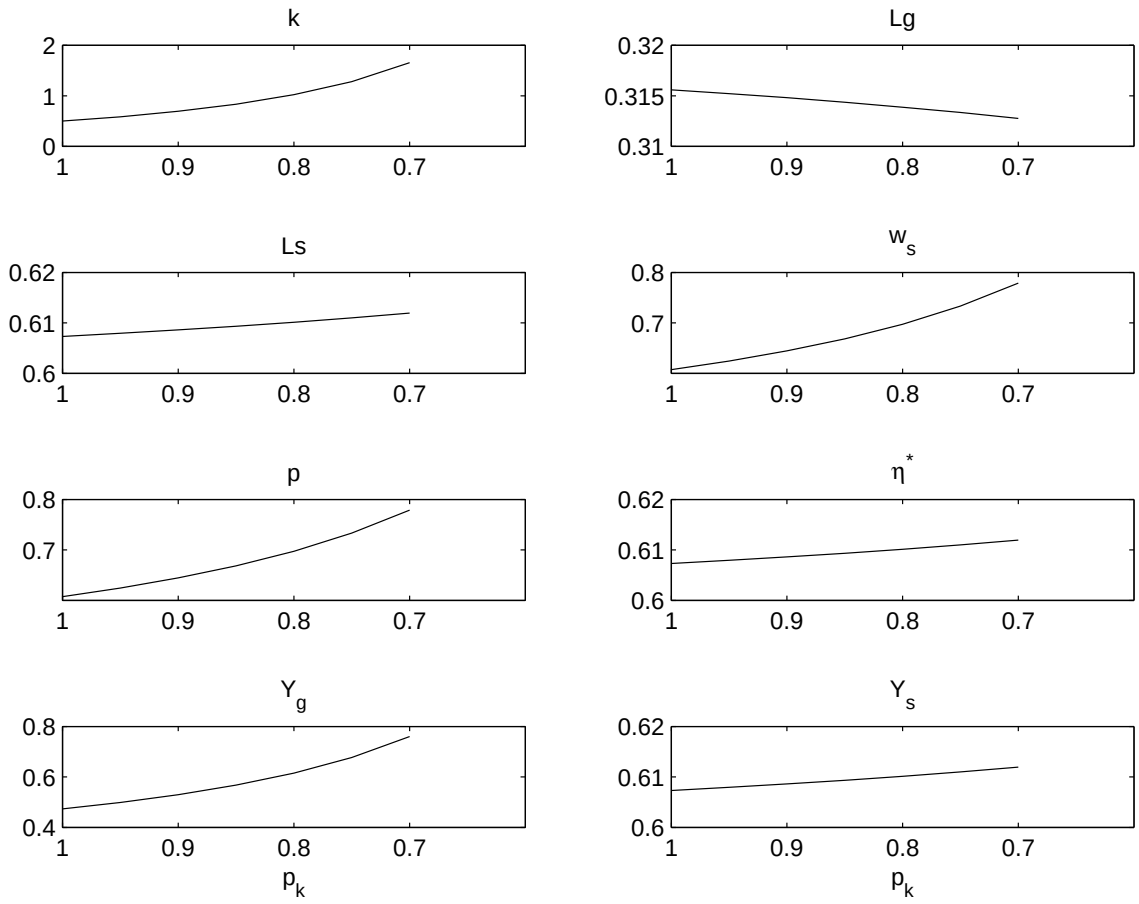


Figure 4: Macroeconomic effects of a fall in p_K

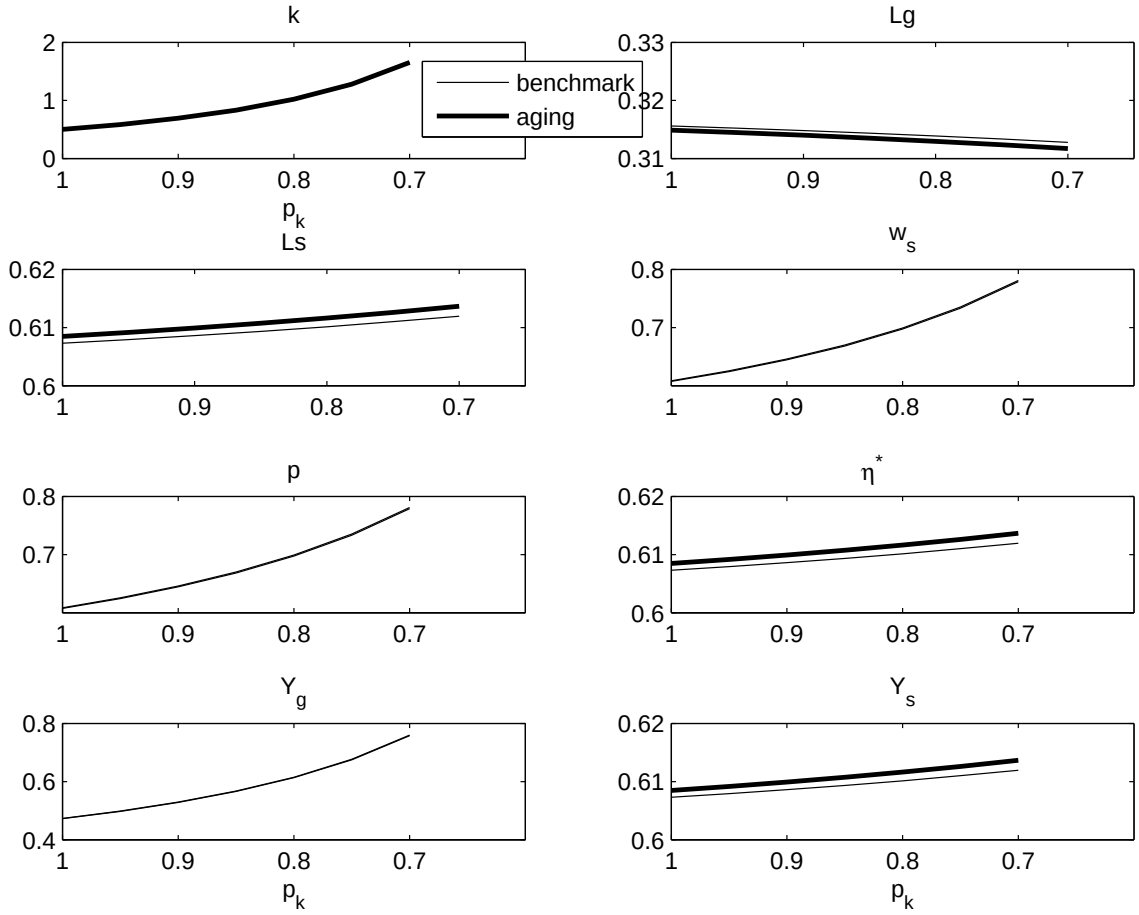


Figure 5: Macroeconomic effects of a fall in p_K : benchmark calibration versus aging economy

k, and on the wage of the good sector, w_r. None of them are affected by the relative size of each consumer type. In contrast, aging modifies the magnitude of the economic mechanisms related to the demand side. With a higher fraction of old consumers, the demand for services expands more than in the benchmark calibration, which amplifies the surge in service employment and the increase in wage inequality measured by $\eta^* = \frac{w_s}{w_r}$.

Column 3 of table 3 reflects well these numerical results. During the 1993-2007 period, the reduction in the price of capital yielded a progressive substitution of workers in routine tasks by machines. These workers could then be allocated to other sectors. In a context of population aging, the demand for personnel services increases, which favors a progressive reallocation of labor towards

this service sector.

In order to have a clearer view of the effect of aging, Figure 6 reports the difference in the economic response in the benchmark calibration versus the aging economy. For each variable X, the graph reports, for each value p_K, the relative difference between both economies

$$\hat{X} = \frac{X_{aging} - X_{benchmark}}{X_{benchmark}} \times 100$$

An upward sloping graph, with $\hat{X} > 0$, means that, as the price of capital falls, the increase in variable X is larger in the aging economy. Symmetrically, a downward sloping graph, with $\hat{X} < 0$, means that, as the price of capital falls, the decrease in variable X is larger in the aging economy. Figure 6 is consistent with the empirical findings reported in section 2: aging magnifies the effects of a decline in the price of capital by leading to an amplified expansion in employment and wage in the service sector, relative to the good sector.

Sensitivity analysis

In this section, we carry out a sensitivity analysis concerning two crucial points in the results reported in figures 5 and 6. First, the bottom line of the paper lies on the heterogeneity in consumers' preferences, and the complementarity between goods and services in the consumption basket of older workers. We therefore report the senstivity of our results to the calibration of ρ_2 that determines the elasticity of substitution between goods and services in old consumers' preferences ($\frac{1}{1-\rho_2}$). Figure 7 reports, for each variable X, $\hat{X}$ the relative difference between the benchmark economy and the aging economy for $\rho_2 = -0.5$ (benchmark calibration) and $\rho_2 = 0.5$. When goods and services are substitutes in the old consumers' preferences ($\rho_2 = 0.5$, as for young consumers), the fall in the price of goods entices all consumers to consume more goods. The demand for services declines, resulting in a decrease in the relative price of services. The production of services shrinks, as well as service employment. Aging promotes service employment growth in the presence of technological diffusion as long as services and goods are complements in old consumers' preferences. Secondly, in the previous section, it is assumed that, following population aging, the pay-as-you-go system is funded by an increase in the contribution rate. In this sensitivity analysis, the deterioration in the dependence ratio is matched by a decrease in pension. Figure 8 suggest that aging boosts service employment growth as long as their income remains unharmed by the fall in the proportion of young people. Whatever the elasticity of substitution between goods and services in old consumers' preferences (even when goods and services are complements $\rho_2 = -0.5$), the model cannot replicate the expansion in service employment. In a nutshell, aging contributes to the polarization process at the bottom of the job quality distribution if and only if goods and services are

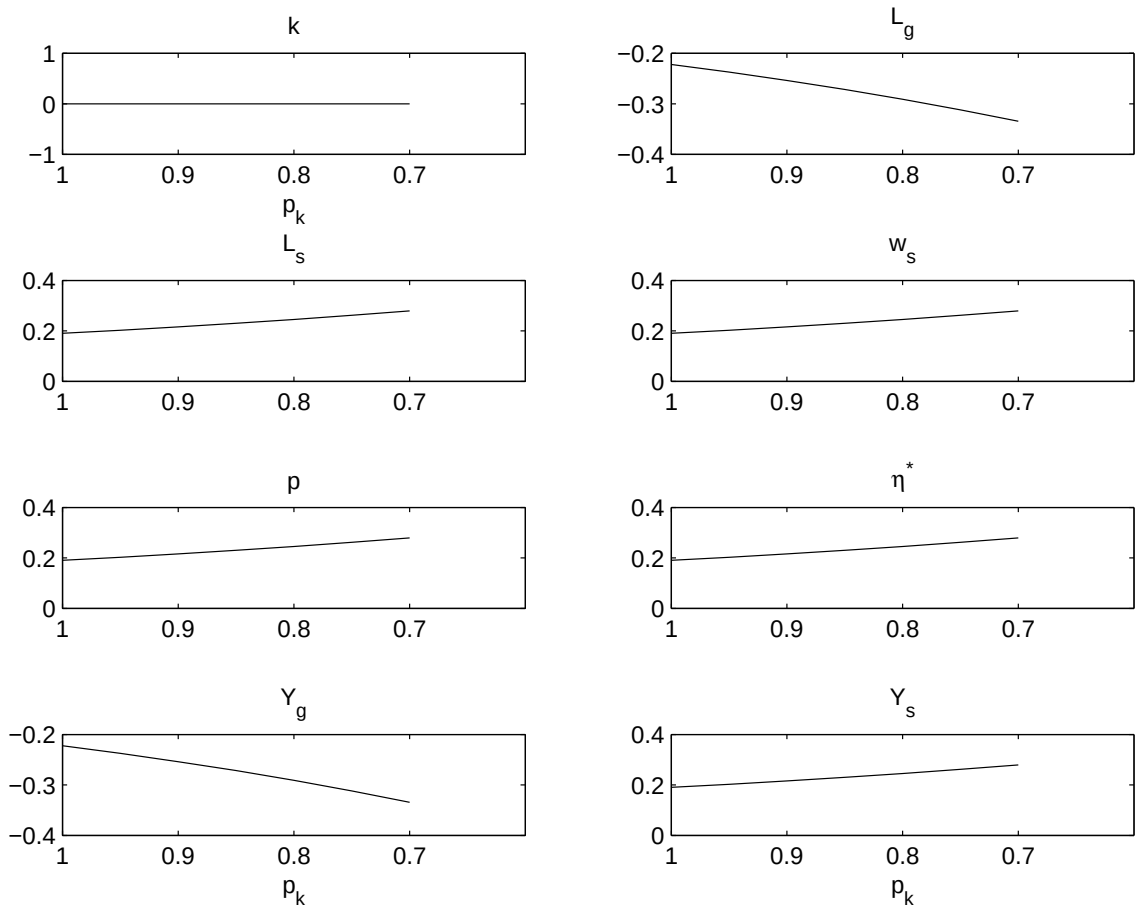


Figure 6: Macroeconomic effects of a fall in p_K : benchmark calibration versus aging economy

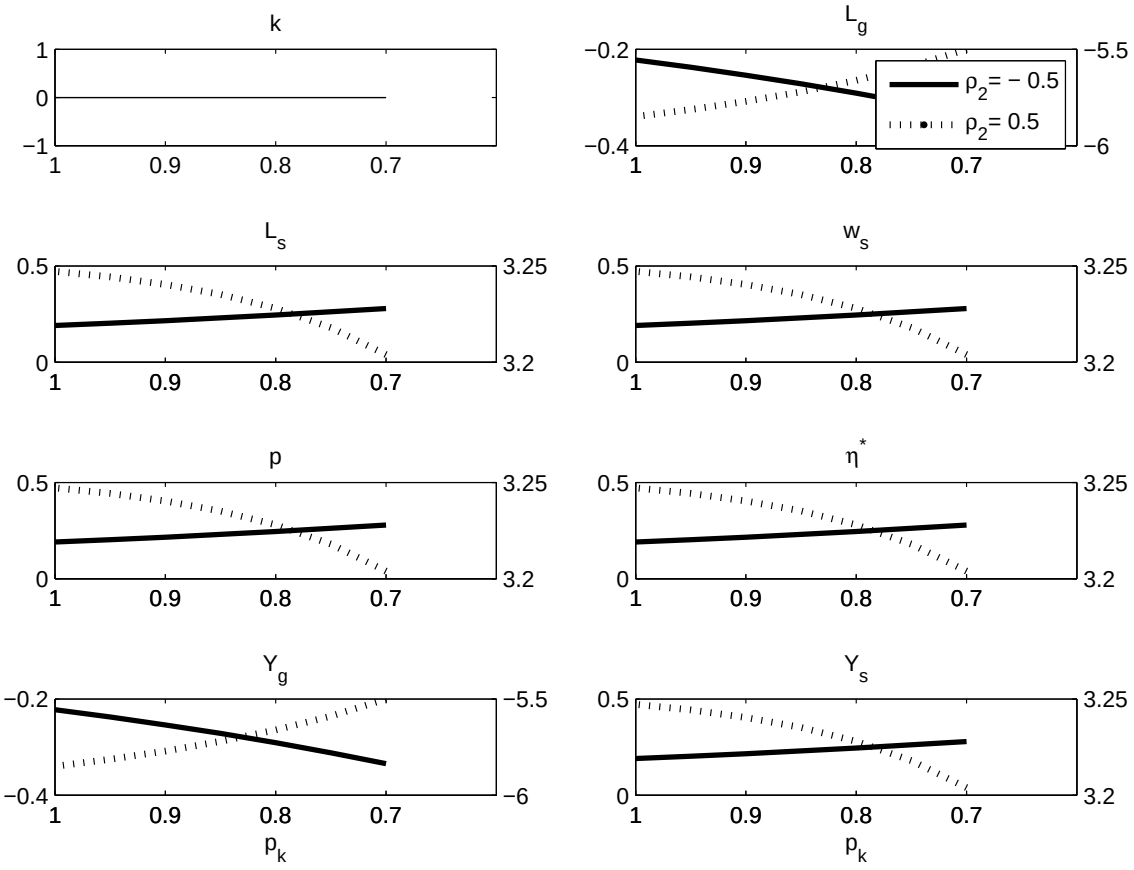


Figure 7: Sensitivity analysis : Alternative values of ρ_2, the contribution rate τ increases. Benchmark calibration versus aging economy.

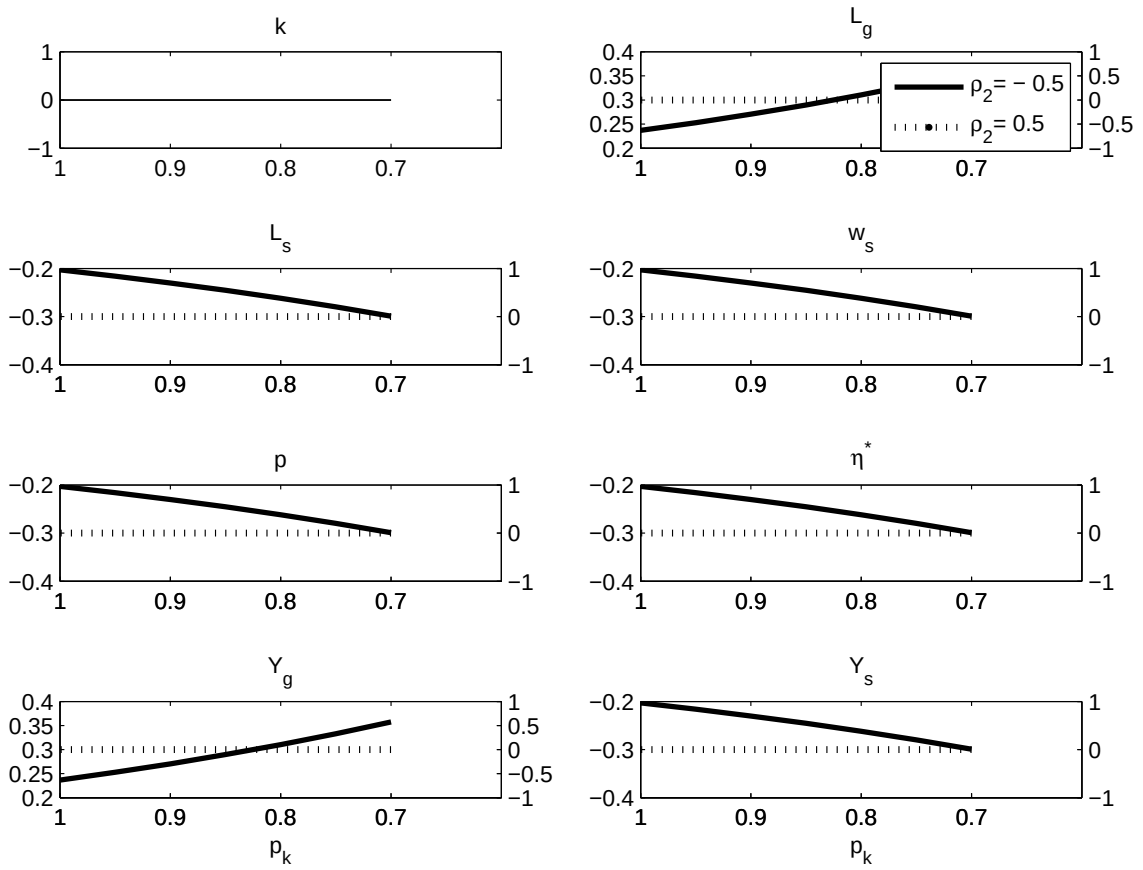


Figure 8: Sensitivity analysis : Alternative values of ρ_2, the contribution rate τ remains constant. Benchmark calibration versus aging economy.

complementary in the old people's preferences and if old consumers' income remains unaffected by the reduction in the dependence ratio. This corresponds well to the empirical findings reported in table 4, where we find that only highly paid old people contribute to the increase in the share of service employment.

5 Conclusion

This paper finds evidence of job polarization on French data, with higher growth rates of employment (and wages) at the top and at the bottom of the wage distribution (U-shaped relationship). We extend on French data the previous findings on US data : the growth in the lower-tail of the wage distribution is linked to the rising employment in personal service occupations. The originality of the paper is to relate the expansion of these low-paid jobs with the simultaneous diffusion of

ICT and population aging.

We present a detailed econometric analysis on the basis French data. We work at the regional level and at a smaller geographical units level. Our benchmark estimation, as well as the various robustness tests we implement, confirm that the rise in service occupation employment is driven by the combined diffusion of ICT and aging. Moreover, the polarization of employment at the bottom of the wage distribution has also favored a progressive reduction in wage inequalities between the first decile and the fifth decile of the wage distribution.

We also develop an analytical framework to shed light on the economic mechanisms behind our empirical findings. We extend Autor and Dorn (2010)'s general equilibrium model to allow for heterogeneous agents and wage inequality. More precisely we consider, on the one hand, young agents that work and that have preferences such that good and services are rather substitutes. On the other hand, we consider old agents, receiving a pension and characterized by more complementary preferences between goods and services. Even if we are unable to provide analytical results, numerical simulations confirm our intuition: combining aging with the progressive decrease in the relative price of goods induced by the diffusion of ICT, explains job polarization towards the service sector since for old people goods and services are complement. This result is consistent with our empirical findings.

APPENDIX

6 Appendix: Definition of jobs

Farmers, civil servants, military and clergymen are excluded from the sample. All jobs related to these categories are dropped from the sample. Some occupations are characterized by a large employment and a vague definition. Following Goos and Maning (2007), each of the following jobs is defined as the specific occupation in a particular industry (15 sectorial activities) : secretary; clerks in financial departments and accounting; cleaners; clerks in various departments; unskilled workers in mechanical works, monitoring and assembly line; courier, messenger; warehouseman, unskilled workers in shipping and transportation; unskilled worker in sorting, wrapping and delivery activities; drivers; executive workers in small firms in finance or administration; storekeeper. The 15 sectors are : Food industry; Consumption Goods; Car industry; Engineering industry; Intermediate goods; Energy; Construction; Trade and repairing; Transportation; Financial activities; Real estate; Services to firms; Services to private individuals; Education, health, social services; Administration. Some jobs may have disappeared while new ones are popping up. The French LFS has modified

the job classification in 2003 in order to take into account the evolution of occupations. We paid attention to have a consistent definition of jobs through the 15 years of our sample. There are no new occupations that cannot be included in the pre-2003 classification.

7 Appendix: Data for regressions

In the sample survey, 21 regions are considered (instead of 22 in the administrative definition of a "region" because data on Corsica are not distinguished from data on the Provence data). In all regressions, regions are weighted by their total population. Jobs included in the service occupation are:

1. coordinator of cultural activities
2. travel agent, self-employed or small firm (0-9 employees)
3. recreational activities (self employed or small firm, 0-9 employees)
4. waiter / waitress
5. hotel staff
6. receptionist
7. accompanying services
8. janitor
9. cleaner in services for private individuals
10. gardener
11. cleaner and staff in private homes
12. child care, family worker
13. auxiliary nurse
14. workers in hospitals
15. ambulance driver
16. specialized nurse

17. nurse for general treatments
18. worker in reeducation, dietician, chiropodist (employee)
19. worker in reeducation, dietician, chiropodist (self-employed)
20. manicure, beautician (employee)
21. hairdresser (employee)
22. manicure, beautician, hairdresser (self-employed)
23. worker on various services to private individuals
24. marriage counselor, family counselor

In table 5, service occupations are divided into categories :

- Miscellaneous: service occupations # 23 and 24 in the list above (worker on various services to private individuals and marriage counselor, family counselor)
- Beauty : service occupations # 20-21
- Health : service occupations # 13-19
- Child Care :service occupations # 12
- House :service occupations # 9-11
- Janitor :service occupations # 6-8
- Recreation :service occupations # 1-5

For want of an accurate description of the tasks involved in each job, we choose among the list of 452 occupations a set of jobs considered as "routine". In order to establish this list, we look at routine jobs identified in Autor and Dorn (2010), Spitz-Oener (2006). Are considered as "routine jobs" the following occupations : typist, keyboarder; operator on computer; office clerk in accounting and financial department in all industries; office clerk in misc. departments in all industries; unskilled workers in mechanics; unskilled workers in extraction; unskilled workers in wrapping, delivery. We check that these jobs are characterized by a 1993 median range that lies in the middle of the 1993 wage distribution (40-60% range).

8 Appendix: A two input factor economy

By means of a simplified two-input model (versus a 3-input model in Autor and Dorn (2010)), we shed light on the economic mechanisms operating behind the polarization of employment towards the bottom of the distribution.

On the supply side, we suppose an economy composed by two perfectly competitive sectors: a good producing sector and service producing sector. Whereas the good sector employs labor and capital to produce a final good, the service sector employs only labor. Since the aim of the paper is to shed light on the reasons underlying the progressive polarization of employment on the bottom of the distribution, we simply consider one type of homogeneous labor that we assume to be non qualified. There is a continuum of mass one of workers, $L_g + L_s = 1$, each of whom supplies either routine labor in the good sector or manual labor in the service sector[16].

The diffusion of ICT is proxied by an exogenous fall in the price of capital. The model will then describe the consequences of cheaper capital on the relative size of the good and service sectors depending on the degree of substitutability/complementarity of capital and labor on the production side and in the degree of substitutability/complementarity between goods and services in the demand side.

8.1 Good-producing sector

The firm's problem is

$$\begin{aligned} &\Pi^g = \max \{Y^g(t) - p_k(t)K(t) - w(t)L_g(t)\} \\ &\text{s.t.} \qquad F(K(t), L_g(t)) \leq Y^g(t) \end{aligned} \tag{24}$$

with Y^g the output in the good sector, K capital, L_g unskilled labor employed in routine tasks in the good-producing sector, p_k the real price of capital and w the real wage. All prices are given and the price of output is normalized to unity.

The FOCs are:

$$\begin{aligned} K &: F'_K(K(t), L_g(t)) = p_k(t) \\ L &: F'_{L_g}(K(t), L_g(t)) = w(t), \end{aligned}$$

[16]Note that Autor and Dorn (2010) deal with the polarization at the top of the distribution, so they also consider the presence of qualified labor implementing abstract tasks in the good sector.

which can be rewritten as

$$\begin{aligned} f'(k(t)) &= p_k(t) \\ f(k(t)) - k(t)f'(k(t)) &= w(t) \end{aligned}$$

with $k(t) = K(t)/L_g(t)$.

8.2 Service-producing sector

The firm's problem is

$$\begin{aligned} &\Pi^s = \max \{p(t)Y^s(t) - w(t)L_s(t)\} \\ &\text{s.t.} \qquad \alpha_s L_s \leq Y^s(t) \end{aligned} \tag{25}$$

where $p(t)$ stands for the ratio between the price of services and the price of goods, $p(t) = p_s/p_g$. Services use only labor as input. The labor demand in the service sector is then such that

$$p(t)\alpha_s = w(t)$$

8.3 The supply side equilibrium: input ratio and prices.

The equilibrium is defined by a set of 3 equations and 3 unknowns:

$$\begin{aligned} f'(k(t)) &= p_k(t) \\ f(k(t)) - k(t)f'(k(t)) &= w(t) \\ p(t)\alpha_s &= w(t) \end{aligned}$$

Proposition. The dynamics of the relative price (p) is governed by the path of the capital price p_k. This is the Balassa-Samuelson result. ■

Proof. For a given value of $p_k(t)$, the first equation determines $k(t)$. Using this result in the second equation, one gets the wage, $w(t)$, and then the last equation yields the relative price for services, $p(t)$. ■

Proposition. The elasticity of substitution between capital and labor determines the dynamics of wages, $w(t)$, and of the relative price of services, $p(t)$, if the price of capital asymptotically decreases

(following the diffusion of ICT). When K and L are substitutes, $w(t)$ and $p(t)$ increase, whereas they decline if K and L are complementary. ■

Proof. Assume that the production is given by a standard CES function:

$$Y^g(t) = [(\lambda K(t))^\mu + ((1-\lambda)(L_g(t)))^\mu]^{\frac{1}{\mu}} \qquad \text{where} \qquad \sigma_r = \frac{1}{1-\mu}$$

with $\mu \in (-\infty; 1]$. Then, the FOC are

$$K: \quad \lambda^\mu k(t)^{\mu-1}[(\lambda k(t))^\mu + (1-\lambda)^\mu]^{\frac{1}{\mu}-1} = p_k(t)$$
$$L: \quad (1-\lambda)^\mu[(\lambda k(t))^\mu + (1-\lambda)^\mu]^{\frac{1}{\mu}-1} = w(t)$$

- If $\mu \in [0, 1]$, then capital and labor are substitutes in the good sector. In case of technological diffusion fostering a decrease in $p_k(t)$, firms will gradually replace labor by capital, yielding a rise in $k(t)$ and a reduction in labor. Because the marginal productivity of workers is improved, wages ($w(t)$) increase and so will the relative price of services ($p(t)$).

- If $\mu \in (-\infty; 0[$, then capital and labor are complementary, which means that both factors increase when $p_k(t)$ decreases. The downturn in the marginal productivity of labor leads to a reduction in wages ($w(t)$) and thus in the relative price of services ($p(t)$).

■

The diffusion of new technologies fosters an increase in the relative price of services $p(t)$ only when $\mu \in [0, 1]$, that is, when capital and labor are relative substitutes. Empirical studies suggest that this is indeed the case in the US (Krusell et al. (2000)). Note though, that the dynamics of the relative price of services is not sufficient to determine the allocation of labor among sectors in the economy. The composition of the aggregate demand must be taken into account when analyzing labor allocation. If the rise in $p(t)$ leads individuals to substitute services for goods, the labor force will not be reallocated to the service sector. In contrast, if, in spite of the rising path of $p(t)$, agents increase their demand for services (when services and goods are complementary according to the agent's preferences), the labor force will be reallocated to the service sector. We must then consider a general equilibrium framework.

8.4 General equilibrium.

The agent's preferences allow us to determine the level of aggregate variables. At the equilibrium, the marginal rate of substitution between services and goods (MRS) must equal p. Because in the presence of technological diffusion p_k shifts over the time, the allocation of labor among sectors

at the equilibrium will also progress along time since the relative price of good and services is modified.

- If the consumer has logarithmic preferences, such that $\mathcal{U} = \log(C_g) + \gamma \log(C_s)$, the MRS is given by:

$$\frac{\mathcal{U}'_{C_s}}{\mathcal{U}'_{C_g}} = \gamma \frac{C_g}{C_s} = \gamma \frac{Y_g - p_k K}{Y_s} = \gamma p \frac{wL_g}{wL_s} = \gamma p \frac{L_g}{1 - L_g}$$

Proposition. For any value of μ, the decline in the price of capital does not affect the employment allocation between sectors. ■

Proof. Because $MRS = p$, we find

$$p = p\gamma \frac{L_g(t)}{1 - L_g(t)} \Leftrightarrow L_g(t) = \frac{1}{1 + \gamma}$$

that is, the share of labor allocated to each of the sectors depends uniquely on the initial composition of the consumption bundle and not on the relative price of goods and services.

More precisely, if capital and labor are perfectly substitutable in the production function, when p_k decreases, the income effect linked to the improvement in wages is completely compensated by the increase in the relative price of services. As a result, the allocation of labor among sectors remains constant and independent of relative prices. ■

- If the agent's preferences are CES, such that $\mathcal{U} = [\nu C_g^{\rho} + (1 - \nu) C_s^{\rho}]^{\frac{1}{\rho}}$, with $\rho \in (-\infty; 1[$, we are in the case studied by Autor and Dorn (2010) but with only two production factors (we do not consider abstract labor). The effects of a progressive decrease in p_k towards zero, induced by the diffusion of new technologies, can be easily analyzed if we consider a central planer framework, as in Autor and Dorn (2010). The optimizing problem becomes in this case:

$$\begin{aligned} Max_{K,L_s} \quad & \{(\alpha_s L_s)^{\frac{\sigma-1}{\sigma}} + (Y_g - p_k K)^{\frac{\sigma-1}{\sigma}}\} \\ \text{where} \quad & \sigma = \frac{1}{1 - \rho} \\ & Y^g = [(\lambda K)^{\mu} + ((1 - \lambda)(L_g))^{\mu}]^{\frac{1}{\mu}} \\ & Y^s = \alpha_s L_s \\ & L_g = g(L_s) \end{aligned} \tag{26}$$

Working with the first order conditions (FOC), we can easily determine the asymptotic behavior of labor services when p_k tends to zero. The FOCs are given by:

$$\begin{aligned} K &: Y^{g\prime}(K) = p_k \\ L_s &: \alpha_s^{\frac{\sigma-1}{\sigma}} L_s^{1/\sigma} = -(Y^g - p_k K)^{1/\sigma} Y^{g\prime}(L_g)\, L_g{}'(L_s) \end{aligned}$$

When $p_k \to 0$, we find a similar result as in Autor and Dorn (2010):

$$L_s^* = \left\{ \begin{array}{rll} 1 & if & \frac{\sigma}{\sigma_r} < 1 \\ L_s \epsilon (0,1) & if & \frac{\sigma}{\sigma_r} = 1 \\ 0 & if & \frac{\sigma}{\sigma_r} > 1 \\ & & \end{array} \right\}$$

where $\sigma = \frac{1}{1-\rho}$ stands for the elasticity of substitution between goods and services (agent's preferences) and $\sigma_r = \frac{1}{1-\mu}$ is the elasticity of substitution between capital and labor (production function).

The asymptotic behavior of labor in a context of technological diffusion, *i.e.* $p_k \to 0$, can be summarized as follows: if the elasticity of substitution between capital and routine labor in the production function, is higher than the elasticity of substitution between goods and services in the utility function, we will find an asymptotic polarization towards the service sector (goods and services are relative complements according to the agent's preferences). Conversely, if the elasticity of substitution between goods and services is relatively high, labor will not polarize towards the service sector.

A simpler intuition can be obtained if we exclusively focus on the consumer's optimizing problem. In this case, the equilibrium is given by the equality between the Marginal Rate of Substitution (MRS) between services and goods and the relative price of services. The MRS is given by:

$$\frac{\mathcal{U}'_{C_s}}{\mathcal{U}'_{C_g}} = \frac{1-\nu}{\nu} \left(\frac{Y_g - p_k K}{Y_s} \right)^{1-\rho} = \frac{1-\nu}{\nu} \left(p \frac{L_g}{1-L_g} \right)^{1-\rho},$$

so that, the optimal consumer's choice implies:

$$p(t) = \left(\frac{1-\nu}{\nu} \right)^{\frac{1}{\rho}} \left(\frac{L_g}{1-L_g} \right)^{\frac{1-\rho}{\rho}} \tag{27}$$

Proposition. If $0 < \rho < 1$, the size of the service sector decreases along the technological diffusion process if $p(t)$ rises (which actually occurs only if capital and routine labor are

substitutes in the production function), whereas for $\rho < 0$, the size of the service sector increases. ■

Proof. From equation (27) we deduce:

- If good and services are substitutes ($0 < \rho < 1$), an increase in the relative price of services (fostered by a decrease in $p_k(t)$ if capital and labor are substitutes) yields a rise in the share of workers employed in the good sector and a decrease in the share employed in the service sector. In this scenario, the substitution effect associated with the rise in $p(t)$ dominates the income effect associated with an increase in wages. More precisely, since goods become relatively less expensive, consumers replace services by goods and so labor concentrates on the good sector.
- In contrast, if goods and services are complements ($\rho < 0$), the rise in the relative price of services yields a decrease in $L_g(t)$ and an increase in $L_s(t)$, since consumers cannot profit from a higher utility by simply consuming goods. Even if goods become cheaper, consumers need to buy both, goods and services. Because the demand for services increases and production in the service sector employs labor as a single input, there will be a reallocation of workers towards this sector whose production needs to raise in order to satisfy a new demand. Note, that the demand for goods is also increased, however, in this case, firms prefer to employ the relative cheaper production input, capital, to increase their production.

■

This simple two-production factor model allows us to shed light on the economic mechanisms underlying behind the polarization process of the labor market over the past decade. These mechanisms can be summarized as follows: technological diffusion is captured by a fall in the price of capital, which yields a rise in the relative price of services with respect to goods only if capital and labor are substitutes in the good producing sector. This fits well with the intuition that unskilled labor in the good sector implements routine tasks that can be easily programmed by computer capital. The rise in the relative price of services leads to an expansion in the employment share of the service sector if and only if goods and services are complements in the agents' preferences. The complementary relationship ensures that the reduction in the relative price of goods induces a simultaneous increase in the demand for goods and services.

Interestingly, ICT diffusion only affects the good producing sector, thereby generating an expansion in good output. The service sector, that does not directly benefit from ICT, suffers from an increase in wages (Balassa effect), that is consistent with our empirical findings. The employment share of the service sector expands, in spite of the increase in wages, because of the significant rise in the demand for services (as long as goods and services are complements).

9 Appendix: The rise in the relative price of services in OECD data

OECD Main Economic Indicators provide a price index for services less housing and a price index for all items less food and energy. We can then compute the ratio of price of services (p_s) to the consumer price index (p_i). The model predicts a rise in $p = \frac{p_s}{p_g}$, the price of services p_s relative to the price of goods p_g. With a CES utility, p and p_i are related in the following way:

$$p_i = \left[(1-\nu_i)^{\frac{1}{1-\rho_i}} p_s^{\frac{\rho_i}{\rho_i - 1}} + \nu_i^{\frac{1}{1-\rho_i}} p_g^{\frac{\rho_i}{\rho_i - 1}} \right]^{\frac{\rho_i}{\rho_i - 1}}$$

This is equation (16). As a result,

$$\frac{p_i}{p_s} = \left[(1-\nu_i)^{\frac{1}{1-\rho_i}} + \nu_i^{\frac{1}{1-\rho_i}} \left(\frac{p_g}{p_s} \right)^{\frac{\rho_i}{\rho_i - 1}} \right]^{\frac{\rho_i}{\rho_i - 1}}$$

Given the equation above, $\frac{p_s}{p_i}$ is positively related to $p = \frac{p_s}{p_g}$. In the data, we find that $\frac{p_s}{P^c}$ indeed goes up, thereby suggesting that the relative price of services $\frac{p_s}{p_g}$ has indeed increased. $\frac{p_s}{P^c}$ is computed based on OECD main economic indicators for France (1960-2009), the UK (1988-2009) and the US (1983-2009), using annual price indices in the Main Economic Indicators. We indeed observe an upward sloping trend in this ratio.

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