Technical change and automation of routine tasks: Evidence from local labour markets in France, 1999-2011

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Abstract – In France as well as in other developed economies, a skill-biased labour demand shift occurred in the past three decades. We test one of the main hypotheses put forward to explain this particular shift: a skill-biased technical change driven by the dissemination of Information and Communication Technologies and the automation of routine tasks, leading to their disappearance in favour of high-skilled and service jobs. Using a theoretical model developed by Autor and Dorn (2013) based on the employment structure of local labour markets to identify national effects of technical change, we find evidence of a link between technical change and the 1990-2011 evolution of the labour force in France. In particular, we find that low-skilled workers switch from routine jobs to service jobs or unemployment. We also find that the shift in labour demand interacts with a spatial functional specialisation. These results are robust when other hypotheses, such as globalisation and the growth of international trade, or demographic change, are taken into account.

JEL Classification : F16, F60, J23, J24, O33, R23
Keywords: technical change, automation, local labor markets

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During the 1990s and 2000s, deep changes have occurred in labour supply and demand in France. The increase in education levels caused a rapid growth in the number of college-educated workers. During the last 20 years, they concentrated in big cities. Following Moretti (2013), Charnoz and Orand (2016) conducted a joint analysis of this concentration and of the relative wage of college-educated workers and pointed out a skill-biased demand shift. The dynamics of the French labour market is therefore close to that of the United States. Several explanations for the demand shift observed in the U.S. have been proposed. They fall roughly in two categories: those that refer to technical change and Information and Communication Technologies (ICT) and those relating to globalization and international trade. In this paper, we investigate the first one for France.

The hypothesis of technical change relates the change in demand for skills to the dissemination of ICT, which are assumed to increase high-skilled workers' productivity more than that of low-skilled workers. For instance, Beaudry *et al.* (2006; 2010) estimate the effect of PC adoption on labour supply and demand by skills across U.S. metropolitan areas. They find that cities initially endowed with relatively abundant and cheap skilled labour adopted PCs more aggressively. The effect of technology on jobs has been defined more precisely by Autor *et al*. (2003) as an automation of routine tasks. Jobs that consist of routine tasks disappear as these tasks can be performed by computers and the price of computers decreases, while abstract or manual tasks remain. This is why the phenomenon is sometimes referred to as "routine-biased technological change" (Goos *et al*., 2014). As shown in Autor and Dorn's theoretical model (2013), the progressive adoption of new technologies and the automation of routine tasks should lead to different evolutions in local labour markets, depending on the initial share of routine tasks for instance. By estimating the evolution of the various types of tasks in these local labour markets, one can identify the effect of technological change on the evolution of the entire labour market. That is what we intend to do for France, showing that the evolution of the different types of tasks across local labour markets is consistent with the technical change and automation hypotheses.

One of the many reasons that lead to study skill-biased technological change is its potential effect on wage inequalities. Abstract tasks being paid at the top of the wage distribution and manual tasks at the bottom, it may indeed lead to a rise in wage inequalities. This is why the automation of routine tasks has often been related to labour market polarisation (Autor *et al*.,2003; Goos *et al*., 2009; Goos *et al*., 2014; Michaels *et al*., 2014; Firpo *et al*., 2011; Machin & van Reenen, 1998). Labour market polarisation refers to increasing proportions of the lowest paid and the best paid occupations, while that of medium-paid occupations declines. It is observed in the U.S. and to some extent in Europe[1] and is an important factor in explaining the increase in wage inequalities. Harrigan *et al*. (2016), on private sector wage data, or Bock (2016), on the basis of employment rate by skill level, have found evidence of such a link between labour market polarisation labour and a shift in labour demand, in particular through the adoption of new technologies.

Another explanation relates the rise of wage inequality to import competition from low-wage countries (Autor *et al*., 2013a; Rigby *et al*., 2015; Keller & Utar, 2016). As trade barriers declined, low-skilled jobs have faced a higher competition than high-skilled jobs, and this could explain a rise in wage inequality between skill levels due to an alignment of the domestic labour cost on the foreign labour cost and to specialisation: indeed, as predicted by trade theory and the Stolper-Samuelson theorem, when trading costs decrease, the return on the abundant factor (high-skilled labour relatively to low-skilled labour in advanced economies) increases.[2] Another explanation referring to international trade is the offshoring of jobs or tasks (Grossman & Rossi-Hansberg, 2008). If certain jobs or tasks can be performed in low-wage countries and the cost of offshoring them decreased (because trade barriers, such as transportation or communication cost, decreased), low-skilled labour demand might have decreased. Note that this phenomenon can partly be related to ICT, in the sense that ICT certainly decreases communication costs. The international trade hypothesis to explain the demand shift and the interaction with technological change is studied in our paper, by testing the robustness of our results to taking into account import competition and offshoring. We find that the effects of technical change and automation are maintained even when taking into account these other hypotheses.

1. In Europe and particularly in France, the share of low-skilled jobs has grown not so much, that's why the pertinence of the use of the concept of polarisation has been discussed (see Jolly (2015) for instance).
2. Although the effect might be opposite as shown by Lorentowicz et al. (2005) in the case of Austria and Poland.

Our empirical strategy is based, as Autor and Dorn (2013), on using the differences between local labour markets to test for these explanations. For the U.S. (Autor & Dorn, 2013; Autor *et al*., 2013a; 2013b) found that import competition had a negative effect on the level of employment for all skill levels. They also found evidence of Skill-Biased Technical Change (SBTC) in both manufacturing and non-manufacturing sectors and showed that, among routine jobs, the share of production jobs decreased first, then the share of information processing jobs (such as clerical jobs).

While these papers used local labour markets mainly as a way to identify a nation-wide phenomenon, another set of papers looked into the spatial component of wage inequalities by skills (Lindley & Machin, 2014; Moretti, 2013). They found that a spatial concentration of high-skilled workers occurred, and related it to a skill-biased spatial shift in labour demand. Similar patterns have been documented for France by Charnoz and Orand (2016). A potential explanation for this spatial shift in labour demand could be that the initial local industrial mix made some local labour markets more exposed to SBTC, offshoring or import competition.

Other mechanisms analyzed in economic geography, such as agglomeration economies and distance related costs, could also contribute to the explanation of this spatial shift. Baum-Snow *et al*. (2014) showed that there has been an increase in agglomeration economies for high-skilled workers in the U.S. They did not study the cause of this increase, but they analyse it as knowledge spillovers, which are often higher for high-skilled workers and may have increased. This skill-biased rise in agglomeration economies would explain a higher concentration and higher wages for high-skilled workers in big and dense cities. Another channel, which in fact links ICT to geography, is the decreasing cost of communication between locations entailed by the communication dimension of ICT, whereas SBTC refers to its contents in terms of information. Duranton and Puga's model (2005) predicts that a fall in communication costs between headquarters and affiliates, leads to a functional specialisation of cities. Some cities specialise in headquarters and business services and other in production activities. Even though their model does not explicitly encompass skills, the fact that headquarters and business services employ more skilled workers could explain that the demand for high-skilled workers has increased more in some cities than others. Evidence of such an increase in the functional specialisation of local labour markets has been found for French firms by Charnoz *et al*. (2016), who study the impact of high-speed train in France on the relation between headquarters and subsidiaries. In order to take into account this phenomenon of functional specialisation, we introduce a new dimension into our analysis, by differentiating support and production functions for the different types of tasks. We show that high-skill jobs have concentrated in areas where the support functions were initially more present. That indicates a functional specialisation and a technical change-led shift in labour demand.

Evidence for France is much scarcer than for the U.S. Aubert and Sillard (2005), Barlet *et al*. (2009) and Fontagné and d'Isanto (2013) proposed an assessment of the extent of offshoring but not of its effects on labourwages. Malgouyres (2016) implemented Autor *et al*.'s (2013a) strategy to test for the effect of import competition in France, and found a negative effect on employment. This effect is polarised in the manufacturing sector wherein it is much stronger for medium-skilled occupations while it is stronger on low-skilled occupations in the non-manufacturing sector. This is different from the results of Autor *et al.* (2013a; 2013b) who did not find a polarising effect of import competition in the U.S. As for the SBTC hypothesis in France, at national level, Goux and Maurin (2000) provided evidence of technical change, but to a smaller extent than in the U.S. They found that computers and new production technologies explained a fall of around 15% in the share of unskilled workers (with less than high-school education) in total employment over 1970-1993. In the same way, Pak and Poissonnier (2016), using a macroeconomic decomposition of changes in employment, show that technological change has led to a fall in employment of roughly 1% each year, with a bias in favour of high-skilled workers. Goos *et al*. (2009) studied the distribution of employment between occupations in Europe and found evidence of job polarisation in France between 1993 and 2006. Machin and van Reenen (2001) used a panel on seven OECD countries between 1973 and 1989, including France, and found a significant association between skill upgrading and R&D intensity. Caroli and van Reenen (2001) find evidence of a skill-biased organizational change in France in the early 1990s (and in the UK in the late 1980s). They show that new form of organization of firms, with fewer layers, is more favourable to high-skilled workers. One

of the potential factors of this delayering could be the decreasing communication costs induced by ICT. To sum up, for France, there is some evidence of a link between ICT and the demand for high-skilled relatively to low-skilled workers but only before the 1990s. For the recent period, there is some evidence that the share of high-skilled jobs and that of the lowest paid low-skilled jobs increased in France, but it has not been related to ICT and there is no evidence of the impact of ICT at the level of local labour markets. So far, the factors the most studied are mostly referring to international trade growth or to institutional nation-level factors, such as exemptions from social security contributions for low-wage jobs. This paper complements the empirical literature for France by studying the link between ICT and labour demand shift.

The next section presents the theoretical model of Autor and Dorn and our extensions to empirically identify the effect of skill-biased technological change on the evolution of French local labour markets. We use data from the French Census at the level of Employment Zones, and add information to distinguish different types of tasks (abstract, routine and manual) and functions (support or production). We show that the evolution of French local labour markets between 1990 and 2011 is consistent with the predictions of the automation theoretical model. These results are robust to the introduction of alternative hypotheses, such as the increase in international competition or offshoring.

Theoretical model and empirical strategy

The routine task automation hypothesis of Autor and Dorn (2013) states that there must be a decline in routine tasks and an increase in manual and abstract tasks, and thus explains why the technical change could be skill-biased. In this paper, we document the spatial dynamics of occupations in France since the 1980s and use local labour markets to test whether there have been such changes in the different types of tasks and therefore confirm the Autor and Dorn (2013) hypothesis.

Theoretical model

More precisely, the main purpose of Autor and Dorn (2013) was to test whether the polarisation of jobs observed in the U.S. is due to non-neutral technical change. The idea is that ICT made the automation of repetitive and more easily codified jobs possible, whereas in-person services such as food services, house cleaning or home care services have not been much impacted by ICT. They formalized this intuition in a theoretical model, which states that production is divided into two sectors, goods and services. Production of goods Y_g combines three factors: routine labour L_r, abstract labour L_a and computer capital K; production of services Y_s uses only manual labour L_m. Services production is only labour intensive ($Y_s=a_sL_m$), whereas the production function for goods is a combination of a CES and a Cobb-Douglas functions:

$$Y_g = L_a^{1-\beta}\left[\left(a_rL_r\right)^{\mu} + \left(a_kK\right)^{\mu}\right]^{\beta/\mu}$$

This production function is based on two main hypotheses: substitutability between computer capital and routine tasks on the one hand, and complementarity between abstract labour and routine input (produced by the combination of routine labour and capital) on the other hand. Because both goods and services are consumed, when computer capital price falls, computer capital substitutes to low-skilled workers for routine tasks in the production of goods and low-skilled workers switch from the goods sector to the service sector. These services being non-storable and non-tradable, low-skilled workers must be located where services are consumed.

The idea of Autor and Dorn (2013) was therefore to use spatial differences in local labour markets to test the routine task automation hypothesis. They applied their model in a spatial setting in which high-skilled labour is mobile between local labour markets, whereas low-skilled workers are immobile. The model predicts the effect of technical change on local labour markets, according to their initial distribution of routine tasks. More precisely, the model predicts four spatial dynamics of labour market outcomes following a fall in computer capital price:

1. the largest decreases in the share of routine jobs take place in areas where routine jobs are initially more numerous;

2. the share of in-person service jobs increases where the share of routine jobs is initially higher as low-skilled workers are reallocated from routine jobs to in-person service jobs;

3. the share of abstract jobs increases more in areas with a high initial level of routine jobs because of their complementarity with ICT capital;

4. wages in manual or abstracts jobs increase more in areas with a high initial level of routine jobs.

The third prediction differentiates the technological change hypothesis from hypotheses linked to the growth of international trade (import competition or offshoring). In the case of technological change, routine tasks do indeed not completely disappear from the production line, but are replaced by computer capital. Routine tasks are still localized in the same area and should also grow. That is why we expect in this case a growth of abstract labour, complementary to abstract tasks, which would not occur in the case of offshoring for instance.

Empirical strategy

Using U.S. data, Autor and Dorn empirical analysis focused mainly on the second prediction as it is related to job polarisation, which is the main stylised fact they documented and wished to explain. They found that the share of in-person service jobs did increase more in local labour markets where the share of routine jobs was initially higher. In the case of France, there is less strong evidence of job polarisation, but this does not mean that the routine task automation hypothesis is not relevant. Therefore, we look for evidence of this hypothesis with the same empirical strategy, testing the predictions of Autor and Dorn's model (2013) for France[3].

We compute the share of routine, low-skill service and high-skill occupations in employment for each local labour market in 1990 and 2011, and study their evolution between these two dates that correspond to the diffusion of ICT in France. We then study the sign of the correlation between these evolutions and the initial share of routine occupations in the area, and compare it to the theoretical prediction. It is worth noting that, in the theoretical framework, the initial share of routine occupations relates to the production technology of the area: Autor and Dorn (2013) argue that the empirical measure must reflect the "long run, quasi-fixed component of their industrial structure". We therefore decide to take the share of routine occupations in 1982 as our "initial share of routine occupations" rather than that of 1990. The 1982 measure, anterior to the period studied and to the bulk of ICT dissemination, is less likely to be correlated to shocks between 1990 and 2011. Autor and Dorn (2013) also implemented an instrumental variables (IV) strategy to address this issue and found similar effects, sometimes larger than with the classical strategy. We cannot implement this IV strategy as we do not have the same type of information (they use 1950 local industry structure). We have therefore to keep in mind that our results might be slightly downward biased. Finally, we propose an extension of the model by splitting the share of routine occupations in 1982 between production and support routine occupations.

Moreover, Autor *et al.* (2013b) found that among routine occupations, the decrease in clerical and low-skilled production jobs did not occur at the same period of time. In other words, the automation of production tasks and of information-processing tasks (performed in clerical jobs, which are mostly support jobs) did not take place simultaneously. It therefore suggests that technical change could have different effects for support functions and for production functions. In the same vein, the model of Duranton and Puga (2005) describes another potential effect of ICT on spatial disparities, linked to the fall in communication costs rather than in information costs. This would lead to an increase in the functional specialisation of cities, with some cities specialising in headquarters and business services, i.e. support functions. If that is the case, technical change might impact local labour markets differently depending on whether they are specialised in support or production activities. This might explain the different results for production routine jobs or support routine jobs. Technically, the automation of clerical and manufacturing functions might also be of a different nature. An addition of our analysis to that of Autor and Dorn (2013) is to examine whether distinguishing production and support routine jobs provides valuable insights.

Moreover, Autor and Dorn's (2013) theoretical model assumes that low-skilled jobs are perfectly transferred from routine occupations to service occupations. Because of the French context of high unemployment, we suspect that some of the destroyed jobs are not recreated. This should lead to an increase in the unemployment rate of low-skilled workers. We test this supplementary hypothesis by estimating the correlation between low-skilled workers' unemployment rate and the initial share of routine occupations across local labour markets, which should turn out to be positive.

3. Except for the prediction concerning wages, for which we have no information in our data base.

Finally, the technological change hypothesis is not the only one related to labour market polarisation: offshoring or import competition can also play an important part. Even though the technological change hypothesis seems more pertinent regarding the growth of high-skilled labour (due to the complementarity between routine tasks and abstract labour), we have to test for these other hypotheses. We do so by taking into account offshoring and import competition in our model, and verifying the robustness of our results.

Data issues and descriptive statistics

Data

Our empirical strategy requires measures of the contents of jobs in routine, manual and abstract tasks. Therefore, we rely on a detailed classification of occupations[4]. Note that, in this paper, skills and occupational classifications refer to jobs while education levels refer to workers: for instance, workers with different education levels can be found within the high-skilled occupation group.

We define local labour markets using "Employment Zones" as defined by Insee on the basis of commuting information. This is very similar to the concept of Commuting Zones used in Autor and Dorn (2013). The 304 Employment Zones in metropolitan France are areas in which the most part of the workers live and work at the same time, with firms recruiting most of their workforce in the same Employment Zone. That allows us to consider Employment Zones as a good approach to local labour markets. Note that, in Autor and Dorn's theoretical model, low-educated workers are immobile between these zones while high-educated workers are mobile. This seems a strong assumption, but actually the model remains valid as long as high-educated workers are more mobile than low-educated workers, which actually is the case in France (Charnoz & Orand, 2016).

Datasets providing detailed information and enough observations at that geographical level are not very numerous. Moreover, since many in-person service jobs are performed by self-employed workers, it is preferable not to rely on wage earners databases such as the DADS (Social Data Annual Declarations). We therefore use the one fourth samples of the French 1982, 1990 and 1999 Censuses and the 2006 and 2011 census surveys, especially the detailed information provided about occupations (classification at the 4-digit level) and labour market status.

These data also provide information on the level of education, allowing to distinguish workers between college education level (post-secondary education) and non-college education level (high-school degree or less). Since the French censuses don't provide any information on wages or earnings, our analysis focuses on the predictions of Autor and Dorn's model for routine, service and high-skilled jobs.

Tasks and occupations

We present now our definition of routine, service and high-skilled jobs based on French data and also that of support and production functions. Our analyses cover the employed labour force, with the employment status used only to compute low-skilled workers' unemployment rate.

For the sake of clarity, we retain seven groups of occupations. We define firstly a group of high-skilled occupations including managers, executives and engineers (table C1-2 in Online complement C1); low and medium-skilled occupations are broken down into the following groups: production and craft, manufacturing, clerical jobs, retail jobs, service occupations and transport, construction or farming[5]. More precisely, (low-skilled) service occupations are occupations in food service, health service (except doctors and pharmacists), home and personal care (Table C1-3 in Online complement C1). At the national level, the shares of high-skilled and service occupations increased between 1982 and 2011, the share of manufacturing and transport-construction-farming occupations decreased, while there was no change in the shares of the other occupational groups (Table 1).

We also characterise occupations according to their intensity in routine tasks. We build a transition matrix between the U.S. and the French classifications of occupations (4-digit level 1982 classification). Then, we use Autor and Dorn's (2013) database on task contents by occupations, computed from the U.S. Dictionary of Occupational Titles descriptions, to allocate a content in routine, manual and abstract tasks to each occupation of the French classification.

4. The information on the industry where they worked is not used, although the local industry mix is used for robustness checks.
5. It is similar as Autor and Dorn (2013), but we separate clerical from retail occupations.

Table 1
Evolution of the distribution of major occupational groups

In %

	1982	1990	1999	2011
Support				
Managers/executives/engineers	13	16	18	20
Clerical	9	9	10	11
Production				
Production/craft	11	10	10	10
Transport/construction/farming	15	12	10	09
Manufacturing	17	14	12	10
Retail	16	17	16	15
Service occupations	19	21	25	25

Coverage: employed labour force, metropolitan France.
Source: Insee, 1982, 1990, 1999 and 2011 *French Censuses*.

Doing this, we assume that the content of jobs is not too much different between France and the US. This is why we use the most detailed level of the classification, in order to limit the consequences of such an assumption. In a similar way to Autor and Dorn (2013), we build a Routine Task Intensity (RTI) index that allows taking into account simultaneously the content of each occupation in terms of abstract, manual and routine tasks[6]. According to this index, clerical and manufacturing occupations are the most routine-tasks intensive, with clerical occupations notably more intensive. Next, we classify all occupations in "support" or "production" occupations. We define management and administrative functions as support occupations (see Online complement C1 for details) and the remainder as production functions. Following Autor and Dorn (2013), we classify the one third of 4-digit level occupations with the highest RTI index in the 1982 distribution of jobs as routine occupations[7]. We then split the group of routine occupations in support routine occupations and production routine occupations (see Figures I and II). Table 2 shows how each of the seven occupational groups is positioned in terms of content in the three types of tasks and RTI index and their distribution between support and production functions. Routine occupations belong mostly to the groups of manufacturing or clerical occupations (especially secretaries, administrative employees, finance and accounting employees).

6. More precisely, the routine task intensity index is equal to log(routine tasks) - log(manual tasks) - log(abstract tasks).
7. We also classify, even if marginally, as routine occupations some occupations in the executive and service occupation groups. The routine occupations classification and the previous classification in 7 groups therefore do not match perfectly.

Table 2
Task intensity of major occupational groups in 1982

	Abstract tasks	Routine tasks	Manual tasks	RTI index
Support				
Managers/executives/engineers	+	-	-	-
Clerical	-	+	-	+
Production				
Production/craft workers	-	+	+	-
Transport/construction/farming	-	-	+	-
Manufacturing workers	-	+	+	+
Retail	+	-	-	-
Service occupations	-	-	+	-

Note: (+) indicates a task value above average across all occupations in 1982 weighted by employment and (-) below average.
Coverage: employed labour force, metropolitan France.
Source: Insee, 1982 *French Census*, Autor and Dorn (2013) database of task intensity by occupations.

Table 3 shows the distribution of the share of routine occupations in employment by Employment Zone in 1982. Across Employment Zones, the share in routine occupations reflects in part the sectorial repartition of employment: it is higher in the north of France, a historically industrial region, in the Paris region and in some cities such as Nantes or Nice. Distinguishing between support routine occupations and production routine occupations shows very different distributions across space. The share of support routine occupations is higher in the Paris region, in the South-East and in large cities. The share of production routine occupations is higher in the North and the East and in some central areas.

Figure I
Classification of routine occupations

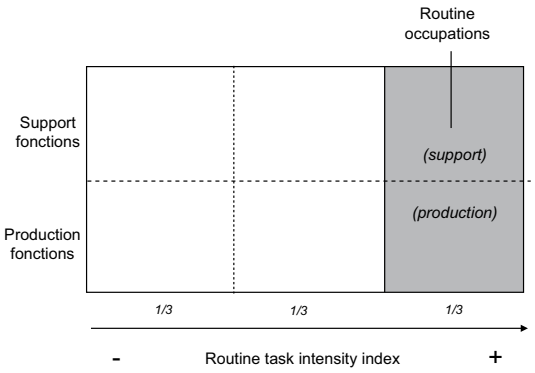


Figure II
Classification of the occupation groups

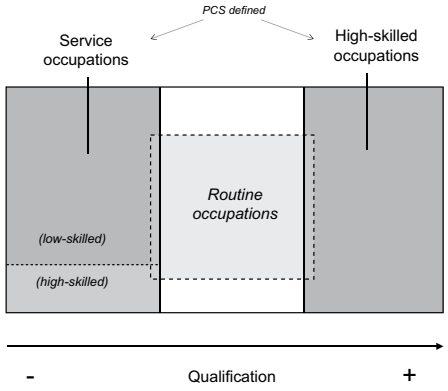


Table 3
Share of routine occupations by employment zone in 1982

Share of routine occupations by Employment Zone (in %)					
All		Production		Support	
Mean	30	Mean	17	Mean	13
Standard error	5	Standard error	4	Standard error	4
Q3	34	Q3	19	Q3	15
Median	30	Median	16	Median	13
Q1	27	Q1	14	Q1	10
Highest 10		Highest 10		Highest 10	
Lille	40	*Charolais*	25	*Poissy*	23
Saint-Dié-des-Vosges	41	*Vallée de la Bresle-Vimeu*	27	*Roissy - Sud Picardie*	24
Créteil	41	*Roubaix-Tourcoing*	27	*Versailles*	24
Saint-Omer	41	*Cholet*	28	*Evry*	25
Marne-la-Vallée	41	*Longwy*	28	*Saclay*	25
Paris	41	*Les Herbiers*	30	*Orly*	26
Orly	41	*Saint-Dié-des-Vosges*	30	*Cergy*	26
Remiremont	42	*Saint-Omer*	30	*Marne-la-Vallée*	26
Roubaix-Tourcoing	46	*Remiremont*	32	*Paris*	26
Vallée de l'Arve	46	*Vallée de l'Arve*	35	*Créteil*	27
Lowest 10		Lowest 10		Lowest 10	
Ghisonaccia-Aléria	12	*Ghisonaccia-Aléria*	6	*Ghisonaccia-Aléria*	6
Saint-Flour	16	*Corte*	8	*Saint-Flour*	7
Carhaix-Plouguer	16	*Saint-Flour*	9	*Carhaix-Plouguer*	7
Porto-Vecchio	17	*Porto-Vecchio*	9	*Mauriac*	7
Mauriac	18	*Carhaix-Plouguer*	9	*Segré*	7
Loudéac	19	*Lannion*	10	*Avranches*	7
Calvi-L'Ile-Rousse	20	*Loudéac*	10	*Brioude*	8
Lannion	20	*Mauriac*	10	*Sablé-sur-Sarthe*	8
Avranches	20	*Guingamp*	11	*Porto-Vecchio*	8
Guingamp	20	*Ajaccio*	11	*La Flèche*	8

Note: the first quartile Q1 indicates that 25% of the employment zones have a lower routine occupations share than its value.
Coverage: employed labour force, metropolitan France.
Source: Insee, 1982 *French Census*, Autor and Dorn (2013) database of task intensity by occupations.

Trends in the spatial distribution of occupations

Before testing the effect of the initial share of routine occupations on the changes in the share of routine occupations, service occupations and high-skilled occupations, we describe briefly their dynamics across French local labour markets over the years 1990-2011, up to now little documented (Tables 4, 5 and 6 respectively for routine, service and high-skilled occupations). A first observation is that routine and service occupations are not located in the same Employment Zones. The share of service occupations is high on the Atlantic and Mediterranean coasts and in some rural areas. The share of routine occupations has decreased over 1990-2011 and seems to be more evenly distributed in 2011 than in 1990. Indeed, when regressing 1990-2011 change on 1990 level, there is a significant negative relationship, meaning a convergence in the level of the share of routine occupations among employment zones (figure III-A). And this is also true when separating between college and non-college employment. The share of high-skilled occupations is higher in large cities and all the more in 2011 than in 1990 (figure III-B)[8].

We do not present the results for high-skilled occupations separately for college and non-college workers as non-college workers in high-skilled occupations are not very numerous. Lastly, the share of service occupations has increased in most employment zones over 1990-2011. For non-college employment, there is a negative relationship between the 1990-2011 change and the 1990 level, meaning also a convergence between employment zones. For college employment in service occupations, the effect is not significant. In the remainder of the article, we focus on the share of service occupations in non-college employment, as Autor and Dorn prediction on service occupations relates to low-educated workers, and for the sake of comparison with their results.

8. Moreover, most of the national evolution of the share of routine, high-skilled and service occupations occurs within the employment zones: with a constant total employment level structure across employment zones between 1990 and 2011, these evolutions are almost identical.

Table 4
Share of routine occupations by employment zone in 1990 and 2011

Share of routine occupations by employment zone (in %)				Evolution of the share of routine occupations by employment zone between 1990 and 2011 (in %)	
1990		2011			
Mean	33	Mean	31	Mean	-2
Standard error	4	Standard error	2	Standard error	3
Q3	36	Q3	33	Q3	-3
Median	33	Median	31	Median	-2
Q1	30	Q1	30	Q1	0
Highest 10		Highest 10		Highest 10	
Roissy - Sud Picardie	41	*Orly*	36	*Saint-Flour*	4
Cergy	41	*Ajaccio*	36	*Carhaix-Plouguer*	4
Créteil	41	*Vallée de la Bresle-Vimeu*	36	*Avranches*	4
Paris	41	*Créteil*	36	*Brioude*	4
Vallée de la Bresle-Vimeu	42	*Cergy*	36	*Ploërmel*	4
Marne-la-Vallée	42	*Marne-la-Vallée*	37	*Royan*	4
Orly	42	*Roubaix-Tourcoing*	38	*Corte*	5
Saint-Omer	43	*Longwy*	38	*Vire Normandie*	5
Roubaix-Tourcoing	45	*Thionville*	38	*Porto-Vecchio*	5
Vallée de l'Arve	48	*Vallée de l'Arve*	39	*Ghisonaccia - Aléria*	7
Lowest 10		Lowest 10		Lowest 10	
Ghisonaccia-Aléria	19	*Saint-Flour*	24	*Vallée de l'Arve*	-9
Saint-Flour	20	*Loudéac*	24	*Cholet*	-8
Carhaix-Plouguer	21	*Mauriac*	24	*Saint-Omer*	-8
Loudéac	21	*Carhaix-Plouguer*	25	*Cambrai*	-8
Mauriac	22	*Pauillac*	25	*Issoudun*	-7
Ploermel	24	*Ghisonaccia-Aléria*	25	*Roubaix - Tourcoing*	-7
Morvan	24	*Thiérache*	26	*Thiers*	-6
Pauillac	24	*Pontivy*	26	*Foix - Pamiers*	-6
Pontivy	25	*Morvan*	26	*Saint-Quentin*	-6
Brioude	25	*Calvi-L'Ile-Rousse*	26	*Orly*	-6

Note: the first quartile Q1 indicates that 25% of the employment zones have a lower routine occupations share than its value.
Coverage: employed labour force, metropolitan France.
Source: Insee, 1990 and 2011 *French Censuses*, Autor and Dorn (2013) database of task intensity by occupations.

Table 5
Share of service occupations by employment zone in 1990 and 2011

Share of service occupations by employment zone (in %)				Evolution of the share of service occupations by employment zone between 1990 and 2011 (in %)	
1990		2011			
Mean	22	Mean	28	Mean	6
Standard error	3	Standard error	3	Standard error	2
Q3	23	Q3	30	Q3	5
Median	22	Median	28	Median	6
Q1	20	Q1	26	Q1	7
Highest 10		Highest 10		Highest 10	
Ussel	27	*Le Blanc*	33	*Calais*	9
Le Blanc	27	*Saint-Amand-Montrond*	33	*Castres - Mazamet*	9
Corte	28	*Verdun*	33	*Vierzon*	10
Céret	28	*Honfleur*	34	*Ghisonaccia - Aléria*	10
Honfleur	28	*Saint-Girons*	34	*Argentan*	10
Berck-Montreuil	30	*Calvi-L'Ile-Rousse*	34	*Saint-Omer*	10
Calvi-L'Ile-Rousse	30	*Ussel*	34	*La Thiérache*	10
Prades	31	*Prades*	34	*Cambrai*	10
Briançon	33	*Berck-Montreuil*	35	*Saint-Amand-Montrond*	11
Menton Vallée de la Roya	34	*Menton Vallée de la Roya*	36	*Commercy*	12
Lowest 10		Lowest 10		Lowest 10	
Vallée de l'Arve	13	*Vallée de l'Arve*	19	*Briançon*	-1
Morteau	14	*Morteau*	19	*Paris*	0
Saint-Claude	15	*Rambouillet*	20	*Le Mont Blanc*	0
Oyonnax	16	*Saint-Quentin-en-Yvelines*	20	*Houdan*	0
Les Herbiers	16	*Paris*	20	*Corte*	1
Wissembourg	17	*Oyonnax*	21	*Menton - Vallée de la Roya*	1
Thiers	17	*Saclay*	21	*Rambouillet*	2
Vallée de la Bresle-Vimeu	17	*Saint-Claude*	21	*Cannes - Antibes*	2
Epernay	18	*Les Herbiers*	22	*La Rochelle*	2
Ambert	18	*Wissembourg*	22	*Montpellier*	2

Note: the first quartile Q1 indicates that 25% of the employment zones have a lower service occupations share than its value.
Coverage: employed labour force, metropolitan France.
Source: Insee, 1990 and 2011 *French Censuses*, Autor and Dorn (2013) database of task intensity by occupations.

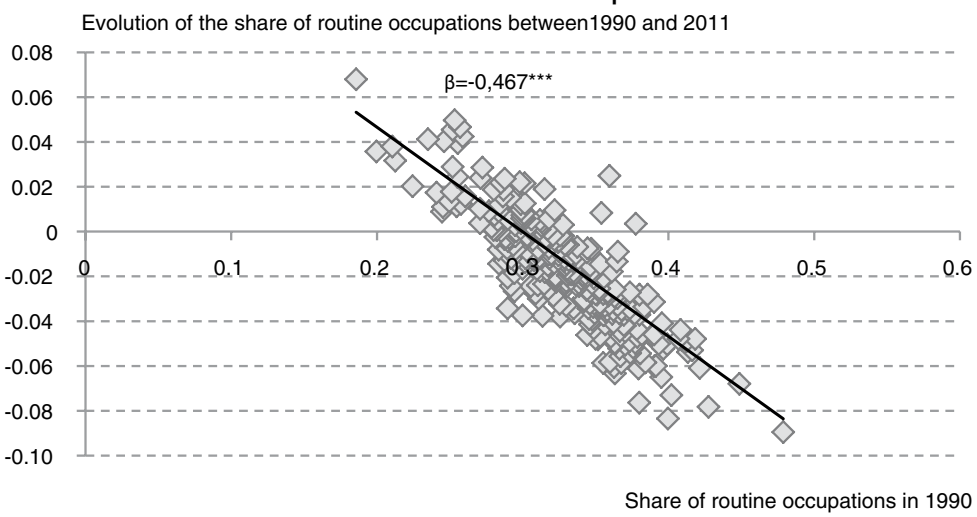
Table 6
Share of high-skilled occupations by employment zone in 1990 and 2011

Share of high-skilled occupations by employment zone (in %)				Evolution of the share of high-skilled occupations by employment zone between 1990 and 2011 (in %)	
1990		2011			
Mean	12	Mean	15	Mean	3
Standard error	3	Standard error	4	Standard error	2
Q3	13	Q3	17	Q3	2
Median	11	Median	14	Median	3
Q1	10	Q1	13	Q1	4
Highest 10		Highest 10		Highest 10	
Cergy	20	*Grenoble*	26	*Rennes*	7
Créteil	20	*Toulouse*	28	*Grenoble*	7
Lille	20	*Aix-en-Provence*	28	*Saclay*	7
Montpellier	21	*Poissy*	29	*Toulouse*	8
Aix-en-Provence	22	*Lille*	29	*Saint-Louis*	9
Paris	23	*Versailles*	30	*Lille*	9
Versailles	23	*Rambouillet*	32	*Poissy*	10
Saint-Quentin-en-Yvelines	24	*Saclay*	35	*Lyon*	10
Rambouillet	26	*Saint-Quentin-en-Yvelines*	36	*Houdan*	12
Saclay	28	*Paris*	40	*Paris*	17
Lowest 10		Lowest 10		Lowest 10	
Mayenne	7	*Péronne*	9	*Brioude*	0
L'Aigle	7	*Mauriac*	10	*Ussel*	0
Morteau	7	*Loudéac*	10	*Chatillon*	0
Louhans	7	*Louhans*	10	*Péronne*	1
Ghisonaccia-Aléria	7	*Chatillon*	10	*Draguignan*	1
Wissembourg	8	*Saint-Flour*	10	*Soissons*	1
Vitré	8	*Brioude*	10	*Tergnier*	1
Segré	8	*Jonzac-Barbezieux-Saint Hilaire*	10	*Verdun*	1
Loudéac	8	*Les Herbiers*	10	*Commercy*	1
Nogent-le-Rotrou	8	*Vallée de la Bresle-Vimeu*	10	*Cambrai*	1

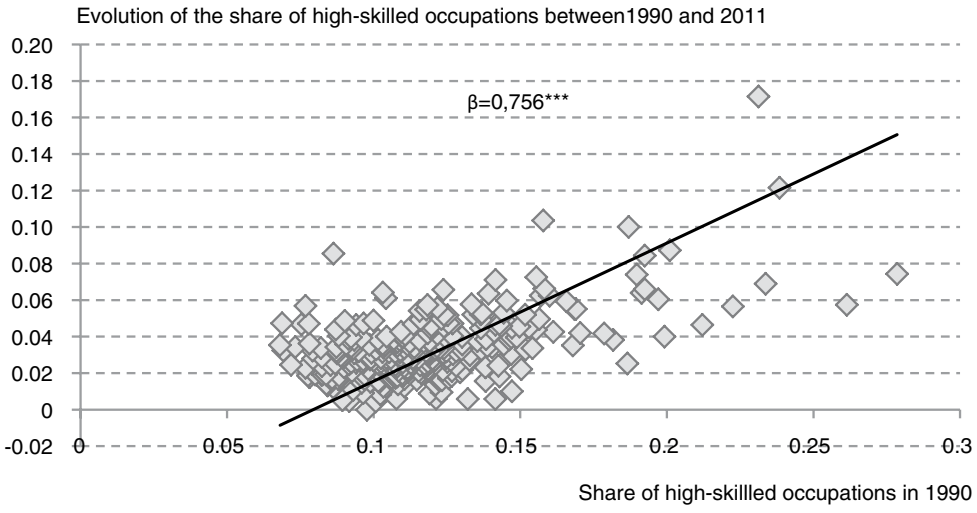
Note: the first quartile Q1 indicates that 25% of the employment zones have a lower high-skilled occupations share than its value.
Coverage: employed labour force, metropolitan France.
Source: Insee, 1990 and 2011 *French Censuses*, Autor and Dorn (2013) database of task intensity by occupations.

Figure III
1990-2011 spatial dynamics of the share of occupations in employment

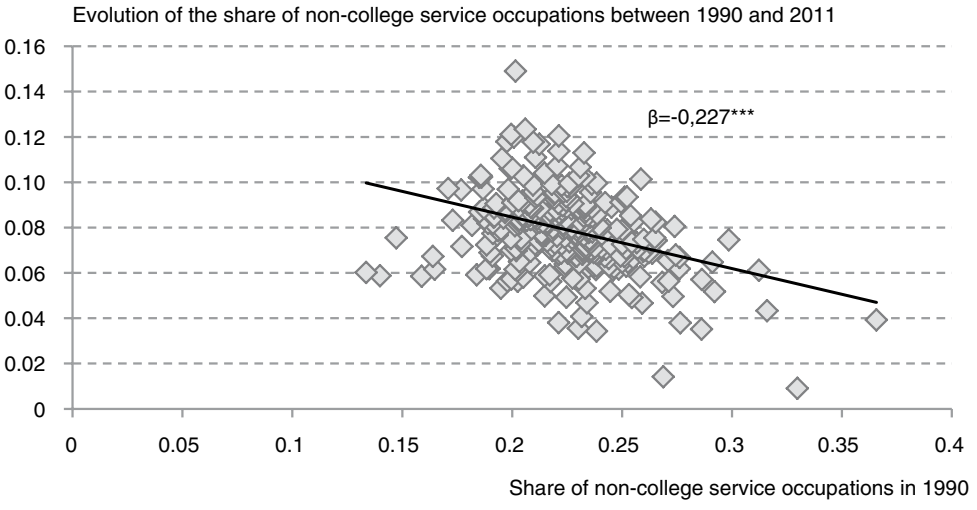
A - Routine occupations



B - High-skilled occupations



C - Non-college service occupations



Note: For each outcome, the change between 1990 and 2011 is regressed on its own level in 1990 (at the employment zone level, 304 observations): $\Delta X_{1990\text{-}2011}=\alpha+\beta*X_{1990}+\varepsilon$. Estimations are weighted by 1982 employment zone population.
*p<0,10 ** p<0,05 *** p<0,01.
Coverage: employed labour force, metropolitan France.
Source: Insee, 1990 and 2011 *French Censuses*.

Routine occupations and ICT

The predictions of Autor and Dorn's (2013) model are based on the fact that ICT can be used to perform routine tasks. Before testing these predictions, we therefore assess whether there is a link between the initial routine level of a local labour market and subsequent dissemination of ICT in the area. We do not have access to a local measure of ICT capital or other measures of ICT dissemination[9] but we know the evolution of ICT capital stock by industry at the national level and the employment composition by industry for each Employment Zone. We therefore build for each zone an "ICT dissemination exposure" index, with a method similar to the import competition exposure index of Autor *et al*. (2013b). We compute, for 1990 and 2011 and each industry, the national level of ICT capital normalized by the employment level in 1982. We use the level of employment in 1982 rather than the current employment level because the current level is probably correlated to ICT capital. For each local labour market and each year, we then apply this national ICT capital per 1982 worker and per industry to the 1982 local employment distribution by industry. This gives an estimation of what the local level of ICT would have been if the employment structure by industry had remained that of 1982 and the local evolution by industry had been the same as at national level. The change in this index between 1990 and 2011 is a measure of how much the employment in a given zone was exposed to ICT dissemination because of its 1982 employment distribution by industry (see Online complement C2 for details). Hereafter, we refer to it as the "1990-2011 change in ICT exposure". This measure is an approximation of the real ICT exposure in the Employment Zone, but has the advantage of being more exogenous than an actual measure of the local level of ICT. It does indeed not take into account the fact that, within an industry, some Employment Zones might have adopted more or less ICT due to unobservable characteristics that could be correlated to our variables of interest, thus biasing the estimations[10].

As the routine tasks automation hypothesis states that ICT should have been adopted more quickly in places where many routine tasks were performed, there should be a positive correlation between ICT dissemination and the initial level of routine occupations in an Employment Zone. Column (1) of Table 7 shows that indeed Employment Zones with a higher share of routine occupations in 1982 were exposed to a significantly higher 1990-2011 change in ICT exposure. In columns (2) and (3) of Table 7, we test this relationship for support and production routine occupations separately. The 1990-2011 change in ICT exposure is significantly related to the initial share of support routine occupations, but not to the initial share of production routine occupations. Given how the measure was built, it means that, between 1990 and 2011, industries with a high share of routine production jobs in 1982 did not experience more or less ICT capital development than those with a low share of routine production jobs. It may be that technical change did not happen in the form of ICT capital in production activities, or that ICT capital in these activities was adopted prior to the period we investigate. On the contrary, industries with a high share of support routine jobs in 1982 experienced a higher development of ICT capital. This furthermore justifies the distinction between

9. ICT capital as it is theoretically defined has a broader spectrum than the accounting definition. It can for instance include robots, that can replace routine workers, as shown in Graetz and Michael (2015).
10. More generally, there is a potential bias of endogeneity between employment structure and technical change or trade. We do not address directly this issue in this paper, since we test stylized facts of a theoretical model rather than estimate an empirical causality.

Table 7
Initial share of routine occupations in employment and 1990-2011 change in ICT exposure by Employment Zone

	1990-2011 change in ICT exposure		
	(1)	(2)	(3)
1982 share of routine occupations	1.792*** (0.282)	1.991*** (0.145)	- 0.427 (0.388)
Type of routine occupation	All	Support	Production
Observations	304	304	304

Note: OLS regression coefficients. Standard errors in parentheses. ICT in thousands of euros. The change in ICT exposure is computed using the national change in ICT capital by worker by industry and weighting for each employment zone by the 1982 local employment share by industry. Estimations are weighted by 1982 employment zone population.
*p<0,10 ** p<0,05 *** p<0,01.
Coverage: employed labour force, metropolitan France.
Source: Insee, 1990 and 2011 *French Censuses*, https://www.insee.fr/fr/statistiques/2832673 (series 6.418) for ICT capital.

support and production routine occupations in the analysis we are conducting afterwards.

A test of the automation hypothesis predictions on French data

We have found evidence that ICT dissemination might be related to a higher 1982 share of routine jobs, particularly for support functions. We now turn to tests of the predictions of Autor and Dorn's model in the French case.

We have seen in the previous section that the share of routine occupations decreased more over 1990-2011 in areas where it was high in 1990. As explained previously, we prefer to use 1982 rather than 1990 as our initial point for the test of Autor and Dorn (2013) predictions. We therefore check that the share of routine occupations decreased more over 1990-2011 in Employment Zones where this share was high in 1982 (column (1) of Table 8). We next regress the 1990-2011 change in the share of high-skilled occupations in employment and in the share of service occupations in non-college workers' employment on the 1982 share of routine occupations by Employment Zone. Results are presented respectively in columns (2) and (3) of Table 8. As predicted by the model, the share of high-skilled occupations has increased more where the share of routine occupations was initially higher, with a positive and statistically significant link. Similarly, the positive and significant link between change in the share of service occupations in non-college workers' employment between 1990 and 2011 and the initial share of routine occupations tends to validate the model of Autor and Dorn (2013).

Lastly, in the theoretical model, the transfer from routine to in-person service jobs relies on the assumption that low-skilled workers are immobile inside their local labour market. In the French context of high unemployment and higher minimum wage, this hypothesis could translate in low-skilled workers moving to unemployment rather than to in-person service jobs, in particular if the demand for in-person services was not strong enough. We therefore test the impact of the initial share of routine occupations on non-college workers' unemployment rate. Column (4) of table 8 shows a significant positive relationship between the initial share of routine occupations and non-college workers' unemployment. So it seems that in the French case, when routine jobs declined, they were not entirely replaced by low-skilled service jobs, hence a growth in the unemployment rate of non-college workers.

The evolution of the French local labour markets appears consistent with the predictions of the theoretical model, and with the hypothesis of a technical change that lead to the automation of routine tasks. We also investigate whether the result holds for the two types of routine tasks, support and production. This allows us to integrate some mechanisms related to functional specialisation, as described for instance in Duranton and Puga (2005), in our analysis. Indeed, the functional specialisation (between production and support –approximated by management functions) of Employment Zones has increased between 1990 and 2011 (Table 9): smaller cities have focused on production occupations whereas bigger cities have specialised in support occupations. The simultaneity of this functional specialisation, that favours support occupations in some areas, and the technical change, that reduces the share of routine tasks, may cause interactions leading to different evolutions for support or production routine occupations.

Table 8
Effect of the initial share of routine occupations on 1990-2011 change in labour market outcomes by Employment Zone

	1990-2011 change in			
	employment share of routine occupations	employment share of high-skilled occupations	non-college share of service occupations	non-college unemployment rate
	(1)	(2)	(3)	(4)
1982 share of routine occupations	- 0.353*** *(0.014)*	0.482** *(0.229)*	0.100*** *(0.025)*	0.266*** *(0.04)*
Observations	304	304	304	304

Note: OLS regression coefficients. Standard errors in parentheses. Estimations are weighted by 1982 employment zone population.
*p<0,10 ** p<0,05 *** p<0,01.
Coverage: employed labour force; labour force for the unemployment rate, metropolitan France.
Source: Insee, 1982, 1990 and 2011 *French Censuses.*

Table 9
Functional specialization by Employment Zone in 1990 and 2011

Local population	Functional specialisation in management against production	
	1990	2011
< 50 000	- 0.52	- 0.52
50 000-100 000	- 0.44	- 0.50
100 000-250 000	- 0.36	- 0.38
250 000-500 000	- 0.17	- 0.19
500 000-1 000 000	0.04	0.08
1 000 000-2 000 000	0.41	0.57
> 2 000 000	1.36	3.49

Note: this measure is similar to the one used in Duranton and Puga (2005). It is the percentage difference from the national average of executives and managers per production worker (occupied in precision production, fabrication or assembly). The last category (more than 2 million people) contains only one employment zone, Paris.
Coverage: employed labour force, metropolitan France.
Source: Insee, 1990 and 2011 *French Censuses*.

Table 10
Effect of the initial share of production and support routine occupations on 1990-2011 change in labour market outcomes by Employment Zone

	1990-2011 change in				
	Employment share of production routine occupations	Employment share of support routine occupations	Employment share of high-skilled occupations	Employment share of non-college service occupations	Non-college unemployment rate
	(1)	(2)	(3)	(4)	(5)
1982 share of production routine occupations	- 0.444*** *(0.022)*	0.028* *(0.015)*	- 0.001 *(0.035)*	0.147*** *(0.023)*	0.223*** *(0.03)*
1982 share of support routine occupations	- 0.050*** *(0.01)*	-0.285*** *(0.015)*	0.621*** *(0.213)*	0.087** *(0.037)*	0.279*** *(0.042)*
Observations	304	304	304	304	304

Note: OLS regression coefficients. Standard errors in parentheses. Estimations are weighted by 1982 employment zone population.
*p<0,10 ** p<0,05 *** p<0,01.
Coverage: employed labour force; labour force for the unemployment rate, metropolitan France.
Source: Insee, 1982, 1990 and 2011 *French Censuses*.

Table 10 presents the same estimations as in the previous section but splitting the initial share of routine occupations into production and support occupations. The share of each type of routine occupations has decreased more in Employment Zones where it was initially higher. Our results hold for the share of service occupations among non-college workers' and non-college unemployment: both have increased more in Employment Zones where the share of production routine occupations in 1982 or that of support routine occupations was initially high. The share of high-skilled occupations has increased more in zones where the initial share of support routine occupations was higher but not in those where the initial share of production routine occupations was higher. This last result contradicts the predictions of Autor and Dorn (2013), particularly that of a complementarity between routine production tasks and abstract tasks. But one could assume that this complementarity does not require geographical proximity, even less as ICT develops and communication costs decreases. If this is the case, the lack of geographical proximity seems more valid for production than for support functions.

For non-college workers, the impact of the initial share of routine occupations has been stronger on the unemployment rate than on the share of service occupations. The higher disappearance of routine occupations in Employment Zones with a higher initial level of the share of routine occupations seems to have led to a higher increase of non-college unemployment rather than of non-college employment in service occupations. Moreover, the effect on the share of services occupations is stronger for production than for support routine occupations. So, it seems that the demand for service occupations

was less important in zones with routine support jobs than in zones with routine production jobs. In Autor and Dorn (2013) theoretical model, results for low-skilled workers are driven by their immobility and the consumer demand for services. The fact that there is a smaller effect on service occupations in the places where the share of high-skilled occupations has increased the most, entails that in, France, the demand for service occupations may not have been due to local workers. In other words, the rise in the demand for service occupations might not have been driven by local workers consumption[11]. Given the places where the rise in service occupations took place, it is more likely to have been due to the aging of the population or to tourism. This would be a demand induced by consumers who were not in the labour force (retired people) or who did not work in these places (tourists).

Other explanations for the skill-biased spatial shift in labour demand

In this section, we try to take into account other potential explanations of the labour demand shift and to see how these factors interact with the technical change and routine tasks automation hypothesis. In particular, we test if the results of the previous section are robust to the introduction of these alternative hypotheses. First we test the results for low-educated workers. The development of international trade is the main alternative explanation for the decrease of demand for low-educated workers: we take it into account in our model by introducing measures of offshoring and import competition, as complementary measures of two main manifestations of the growth of international trade.

The growth of international trade has made cheaper to transfer certain tasks to other countries, especially low-wage countries, and thus incited to offshoring. The more or less offshorable nature of an occupation is possibly correlated to its intensity in routine tasks as easily codified tasks may also be easily offshored. However, some service occupations, even if they were intensive in routine tasks, are less easily offshorable: this is especially the case of services that have to be produced precisely where the consumer is located. Autor and Dorn (2013) use a measure of job offshorability based on two variables of the US Department of Labour Occupational Information Network database: Face-to-Face contact and On-site job. "The measure captures the degree to which an occupation requires either direct interpersonal interaction or proximity to a specific work location." We use their database to compute a similar measure for French occupations, with the method we used for the task intensity of occupations. Table 11 shows that the occupations with the highest level of offshorability are clerical occupations. Low-skilled manufacturing occupations are not considered much offshorable according to this measure[12]. We then calculate the average level of this index of offshorability in each Employment Zone across occupations and we use the 1982 level of this average level for our robustness check. In all the Employment Zones, this measure is positively correlated to the share of support routine occupations in 1982, but not to the share of production routine occupations.

11. The hypothesis of a skill-biased consumption to explain the skill-biased shift in demand is then less credible. Pak and Poissonnier (2016) also find that the domestic demand has a rather unbiased effect on employment.
12. This result may seem surprising at first, but is consistent with most of the offshorability measures (Blinder & Krueger, 2013).

Table 11
Offshorability of major occupation groups

	Offshorability index
Support	
Managers/executives/engineers	-
Clerical	+
Production	
Production/craft workers	+
Transport/construction/farming	+
Manufacturing workers	-
Retail	-
Service occupations	-

Note: (+) indicates a value above average across all occupations in 1982 weighted by employment and (-) below average.
Coverage: employed labour force, metropolitan France.
Source: Insee, 1982 *French Census*, Autor and Dorn (2013) database of offshorability by occupations.

A second channel of the impact of globalisation on labour demand by skills is through import competition. Globalisation might have induced stronger import competition in industries employing low-skilled workers and thus a decrease in the demand for these jobs, that are possibly routine jobs, in the manufacturing sector for example. We construct an indicator of exposure to import competition based on the sectorial structure of each Employment Zone, very similarly to the measure used in Autor *et al*. (2013a) and to our previous ICT dissemination exposure index. More precisely, we apply the national level of import per employment per industry to the 1982 employment per industry in each Employment Zone. We then use the 1990-2011 change in this indicator of import competition exposure. It measures the extent to which the local employment structure by industry was exposed to import competition in 1982, given how import evolved nationally between 1990 and 2011 (see Online complement C2 for details). Table 12 shows that this indicator is positively and significantly

Table 12
Initial share of routine occupations and 1990-2011 import competition exposure by employment zone

	1990-2011 change in import competition exposure		
	(1)	(2)	(3)
1982 share of routine occupations	1.007*** *(0.207)*	0.396** *(0.179)*	1.386*** *(0.387)*
Type of routine occupation	All	Support	Production
Observations	304	304	304

Note: OLS regression coefficients. Standard errors in parentheses. Estimations are weighted by 1982 employment zone population.
*p<0,10 ** p<0,05 *** p<0,01.
Coverage: employed labour force, metropolitan France.
Source: Insee, 1982, 1990 and 2011 *French Censuses*, https://www.insee.fr/fr/statistiques/2832661 (series 5.405) for import data.

Table 13
Robustness of the effect of initial routine share on 1990-2011 change in low-skilled labour markets outcomes by employment zone

	1990-2011 change in the non-college employment share of service occupations				
	(1)	(2)	(3)	(4)	(5)
1982 share of routine occupations	0.105*** *(0.023)*	0.123*** *(0.027)*	0.092*** *(0.024)*	0.082*** *(0.031)*	0.085*** *(0.029)*
1982 female participation	- 0.01 *(0.026)*				-0.018 *(0.026)*
1982 share of 75 year olds		0.112** *(0.052)*			0.212*** *(0.048)*
1982 offshorability index			0.001 *(0,001)*		0.002** *(0.001)*
1990-2011 change in import exposure				0.005*** *(0.002)*	0,009*** *(0.002)*
Observations	304	304	304	304	304
	1990-2011 change in non-college unemployment rate				
	(1)	(2)	(3)	(4)	(5)
1982 share of routine occupations	0.221*** *(0.019)*	0.256*** *(0.05)*	0.164*** *(0.024)*	0.246*** *(0.048)*	0.122*** *(0.03)*
1982 female participation	0.106*** *(0.022)*				0.094*** *(0.027)*
1982 share of 75 year olds		- 0.053 *(0.064)*			0.008 *(0.045)*
1982 offshorability index			0.007*** *(0.001)*		0.004*** *(0.002)*
1990-2011 change in import exposure				0.006** *(0.003)*	0.011*** *(0.003)*
Observations	304	304	304	304	304

Note: OLS regression coefficients. Standard errors in parentheses. Estimations are weighted by 1982 employment zone population.
*p<0,10 ** p<0,05 *** p<0,01.
Coverage: employed labour force; labour force for the unemployment rate, metropolitan France.
Source: Insee, 1982, 1990 and 2011 *French Censuses*, https://www.insee.fr/fr/statistiques/2832661 (series 5.405) for import data.

correlated to the share of routine occupations in 1982, and more strongly to the share of production routine occupations than to that of support routine occupations.

We then add the 1982 offshorability and the 1990-2011 import competition exposure as controls in our regression of 2011-1990 change in the share of service occupations in non-college workers' employment and unemployment rate on the initial share of routine occupations (Table 13 and Table 14 distinguishing support and production functions). They are positively correlated to the share of service occupations in non-college workers' employment and to their unemployment. The effects of the initial share of routine occupations, either distinguishing between production and support functions or not, are lower than previously but still significant. As for the intensity of effects[13], those of the initial share of routine occupations and import competition are comparable, whereas the effect of offshorability is slightly less important. Our results for the test of the task automation hypothesis are thus still valid once controlled for offshoring and import competition[14].

As mentioned earlier, given that the share of service occupations among non-college workers increases more in places where the share of high-skilled occupations decreases, it is likely that the "skill-biased consumption" (that is the greater service demand from high-skilled workers than from low-skilled workers) has no or little influence on the evolution of French local labour markets. But demand for in-person services could also be driven by demographic changes. Increasing female participation in the labour market may increase the demand for services that were previously home produced such as cleaning or childcare. The aging of the population may induce a higher demand for home care services. To avoid a spurious

13. One can compare the effect of the different variables by multiplying the estimated value of the coefficient by the standard-error. This is comparable to use a model with standardized variables.
14. But we do not rule out that globalization might have an effect too.

Table 14
Robustness of the effect of initial share of support and production routine occupations on 1990-2011 change in low-skilled labour markets outcomes by employment zone

	1990-2011 change in the non-college employment share of service occupations				
	(1)	(2)	(3)	(4)	(5)
1982 share of production routine occupations	0.148*** *(0.024)*	0.161*** *(0.024)*	0.140*** *(0.023)*	0.104*** *(0.027)*	0.083*** *(0.024)*
1982 share of support routine occupations	0.084** *(0.035)*	0.110*** *(0.04)*	0.039 *(0.044)*	0.078** *(0.038)*	0.086* *(0.048)*
1982 female participation	0.006* *(0.03)*				-0.018 *(0.025)*
1982 share of 75 year olds		0.103* *(0.057)*			0.214*** *(0.06)*
1982 offshorability index			0.003 *(0.002)*		0.002 *(0.001)*
1990-2011 change in import exposure				0.005*** *(0.002)*	0.009*** *(0.002)*
Observations	304	304	304	304	304
	1990-2011 change in non-college unemployment rate				
	(1)	(2)	(3)	(4)	(5)
1982 share of production routine occupations	0.236*** *(0.031)*	0.217*** *(0.031)*	0.201*** *(0.029)*	0.147*** *(0.035)*	0.125*** *(0.037)*
1982 share of support routine occupations	0.213*** *(0.024)*	0.269*** *(0.054)*	0.123*** *(0.036)*	0.263*** *(0.042)*	0.119*** *(0.038)*
1982 female participation	0.112*** *(0.025)*				0.094*** *(0.027)*
1982 share of 75 year olds		-0.043 *(0.067)*			0.005 *(0.049)*
1982 offshorability index			0.008*** *(0.001)*		0.004** *(0.002)*
1990-2011 change in import exposure				0.009*** *(0.003)*	0.011*** *(0.003)*
Observations	304	304	304	304	304

Note: OLS regression coefficients. Standard errors in parentheses. Estimations are weighted by 1982 employment zone population.
*p<0,10 ** p<0,05 *** p<0,01.
Coverage: employed labour force; labour force for the unemployment rate, metropolitan France.
Source: Insee, 1982, 1990 and 2011 *French Censuses*, https://www.insee.fr/fr/statistiques/2832661 (series 5.405) for import data.

correlation between the level of the share of routine occupations and these demographic variables, we should take them into account in our model. When adding the 1982 female participation rate and the 1982 share of elderly people (over 75 years old) as control variables, results remain pretty similar for the share of service occupations in non-college workers' employment and unemployment rates (cf. Tables 13 and 14) and for routine occupations (table C3-1 Online complement C3).

Introducing controls for import competition and offshoring does not change much the results from our main specification (Table 15). Other competing explanations for the concentration of high-skilled workers in some zones are the functional specialization of large cities proposed by Duranton and Puga (2005) or an increase in the agglomeration economies for high-skilled jobs (Baum-Snow *et al*., 2014). If Employment Zones with a high density of population (and thus potentially high agglomeration economies) are the same as those with a high initial level of support routine occupations, then it may bias our estimation. We therefore add the 1982 population density as a control variable (table 15).

First, we see that a higher density in 1982 is indeed significantly correlated to a higher increase in high-skilled occupations between 1990 and 2011. As high-skilled jobs are mainly support functions, it is consistent with the functional specialization of cities modelled by Duranton and Puga (2005).

Second, previous results hold. The share of high-skilled occupations increased more in Employment Zones where the share of support routine occupations was high but not those where the share of production routine occupations was high. So the evidence of a spatial complementarity between support routine tasks and abstract tasks remains.

Table 15
Robustness of the effect of initial share of support and production routine occupations on 1990-2011 change in the share of high-skilled occupations by Employment Zone

	1990-2011 change in the share of high-skilled occupations			
	(1)	(2)	(3)	(4)
1982 share of production routine occupations	- 0.055* *(0.029)*	- 0.041 *(0.039)*	- 0.018 *(0.042)*	- 0.075** *(0.032)*
1982 share of support routine occupations	0.198*** *(0.065)*	0.327*** *(0.081)*	0.618*** *(0.213)*	0.166*** *(0.059)*
1982 density	0.013*** *(0.001)*			0.012*** *(0.001)*
1982 offshorability index		0.015*** *(0.006)*		0.002 *(0.003)*
1990-2011 change in import exposure			0.002 *(0.003)*	0.002 *(0.002)*
Observations	304	304	304	304

Note: OLS regression coefficients. Standard errors in parentheses. Estimations are weighted by 1982 employment zone population.
*p<0.10 ** p<0.05 *** p<0.01.
Coverage: employed labour force, metropolitan France.
Source: Insee, 1982, 1990 and 2011, *French Censuses*, https://www.insee.fr/fr/statistiques/2832661 (series 5.405) for import data.

Conclusion

We find evidence of the automation of tasks, both in production and support functions, in France over 1990-2011. More precisely, we show that with the development of ICT, low-skilled workers switch from routine tasks to service occupations (manual tasks), or to unemployment. This could explain the skill-biased demand shift and its spatial expression.

At the same time, a functional specialization of local labour markets seems to have occurred over the period 1990-2011 and probably contributed to the spatial shift in demand. High-skilled jobs concentrated in zones where the share of high-skilled occupations was initially higher, and where support routine jobs were also over-represented.

These results are robust to the introduction of controls relating to other explanations such as offshoring of jobs, import competition, or agglomeration economies. However, it cannot be excluded that they have played a role too. Assessing their effects is beyond the scope of this analysis and left for further research. □

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