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Economic crisis accelerates urban structural change via inter-sectoral labour mobility

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Straulino, S., Diodato, D., O'Clery, N.

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Contact information
Pietro Moncada-Paternò-Castello
Address: Edificio Expo. c/ Inca Garcilaso, 3. E-41092 Seville (Spain)
E-mail: jrc-b3-secretariat@ec.europa.eu
Tel.: +34 954488388
Fax: +34 954488316

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Executive Summary

Resilience in the evolutionary economic geography literature has recently been defined as the ability of a city or region to adapt to a shock, rather than return to a pre-shock state. In this paper, we connect this literature to that of urban structural change to investigate the role of labour mobility in urban resilience to economic shocks. Specifically, we propose that cities reallocate their labour via job switches into 'related' sectors in response to a shock.

In order to study labour market mobility over time, we use the Annual Survey of Hours and Earnings dataset (ASHE) dataset which followed 1% of UK workers over a 20 year period (1997-2018). We find that the rate of job churn and inter-industry job switches starts to increase in 2009, and peaks in 2011 before slowly declining. By 2018, it had not returned to pre-crisis switching rates.

Next, we develop an empirical model to predict employment growth at the city-industry level based on the size of employment in related industries in a city. Our dataset is the Business Register and Employment Survey (BRES), which contains information on employment by city and industry between 2009 and 2018. Our key predictive metric is termed 'related employment' in the literature, and uses a normalised measure of labour mobility between sectors (constructed using the ASHE dataset above) in order to infer pairwise industry relatedness. We find that employment growth is most strongly associated with related employment during the immediate post crisis period of employment decline (2008-2011).

We interpret this result as suggesting that cities that can re-allocate workers into skill-related sectors fare better in terms of employment growth during the crisis period. Finally, we investigate the rate of structural change of UK cities between 2005 and 2018, by measuring the sum of the changes (in absolute value) of industry employment shares. We find that the rate of change increased immediately post crisis, peaking in 2009 before declining quickly back to base rates by 2010, thus connecting our findings to structural transformation of cities.

While previous work pointed out that crises may be catalysts for transformation, the connection between economic crisis, industry switching and structural change is intuitive but – to our knowledge – novel in the academic literature. We use our results to infer that cities that have employment in sectors connected by strong labour mobility are better equipped (via an evolutionary ability to adapt) to withstand a crisis and minimize unemployment.

As these findings give an indication regarding possible policy interventions – for instance efforts to build improve mobility between sectors through training schemes, job placements and other instruments – future research could focus on direct tests of the impact of these policies on the resilience of cities.

Economic crisis accelerates urban structural change via inter-sectoral labour mobility

Daniel Straulino[1], Dario Diodato[2], Neave O'Clery[1,3,4,*]

[1]Centre for Advanced Spatial Analysis, University College London, UK
[2]European Commission, Joint Research Centre, Spain
[3]Alan Turing Institute, UK
[4]Mathematical Institute, University of Oxford, UK
[*]Corresponding author

Are recessions drivers of structural change? Here we investigate the resilience of cities, and argue that a re-allocation of labour between industrial sectors in times of crisis induces an acceleration in structural change. Using UK data, we find that cities experienced a sharp increase in inter-sectoral job transitions, and that local employment in skill-related sectors is most strongly associated with employment growth, during the recession, which we identify with the period of employment contraction between 2008 and 2011. This coincides with a massive but short-lived increase in the rate of structural change (i.e. the total change in employment shares of different industries) around 2009. These findings suggest that cities with skill-related sectors re-allocate workers in a crisis, thus inducing structural change.

JEL codes: R11, R12, O14, J62

Key words: Cities, resilience, financial crisis, labour markets, structural change, labour mobility

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1 Introduction

The study of the drivers of structural change, whereby cities evolve their production basket over time, is of fundamental importance to local economic, skills and industrial policy. The study of structural change has roots in a variety of economic disciplines including economic growth theory (Kaldor et al., 1967; Kuznets, 1973; Pasinetti, 1983) and evolutionary economics (Metcalfe et al., 2006). A recent focus of the field has been de-industrialisation and the growth of services relative to manufacturing (Martin and Rowthorn, 1986; Moretti, 2012), and more recently automation. A burgeoning literature examines the diverging trajectories of cities (Martin et al., 2016), with 'shrinking cities' (Pallagst et al., 2013) contrasting with 'renaissance cities' (Glaeser, 2005). This divergence has been linked to the ability of a city to 'cope' with de-industrialisation, and is thought to be driven by variety of factors including agglomeration effects, human capital and innovation capacity (as reviewed by Tyler et al. (2017)).

Here, we ask if an economic crisis such as the 2008 financial crisis can accelerate structural change via inter-sectoral mobility. Specifically, we focus on regional and urban labour markets, and the effect of the crisis on local employment growth, labour mobility and sectoral composition. We posit that inter-industry mobility is a key mechanism for labour market resilience or adaptability: simply put, as economic downturns disproportionately hit particular sectors, workers in well connected cities can more easily change industry to find new work. Hence, cities with more developed inter-industry linkages are best positioned to facilitate such moves and experience accelerated structural change. Most closely related to our study, Diodato and Weterings (2015) probed the role of inter-industry mobility in the speed of recovery of Dutch regions to various sectoral shocks, finding its role particularly important for services industries.

Traditionally, resilience has been studied from an equilibrium based perspective, whereby resilience is linked to be ability of a system to return to a pre-equilibrium state (the 'engineering approach') or to shift to a new equilibrium state (the 'ecological approach') (Simmie and Martin, 2010). Recently, an 'evolutionary' approach to regional resilience has emerged, whereby a regions' resilience is a function of its ability to adapt to an adverse shock (Boschma, 2015; Martin and Gardiner, 2019a). This view emphasises the role of regional diversification and branching into new growth paths, thereby evolving and adapting rather than returning to a previous pre-crisis state.

Much of this thinking emerges from evolutionary economic geography, which emphasises the role of embedded capabilities and know-how in the local work-force (Nelson and Winter, 1982; Boschma, 2009). Experience and knowledge built up 'on the job' endow the workforce with sticky skills, those that are tacit and tricky to transport

(Hausmann, 2016). It is these embedded skills that constrain the development paths such that cities and regions tend to diversify into related industries and technologies, i.e., those that share similar inputs and capabilities (see review by Hidalgo et al. (2018)). A large empirical literature has shown that path dependence is a feature of regional and urban diversification and growth dynamics across a wide range of contexts and geographies (Hidalgo et al., 2007; Frenken et al., 2007; Neffke et al., 2011). Our focus here, inter-industry mobility has been used as a form of relatedness (Neffke and Henning, 2013a), and used to explain employment growth and industry diversification in a range of contexts (Neffke et al., 2011; O'Clery et al., 2016; O'Clery et al., 2019; Landman et al., 2020).

Recently, a number of authors have empirically investigated the ideas behind an evolutionary model of resilience. These studies broadly far into two categories: those that link resilience to industrial variety (both related and unrelated variety of Frenken et al. (2007)), and those that link resilience to relatedness (industrial, occupational and technological). In general there is little consensus with respect to the drivers of resilience within this nascent literature. In the first category, Essletzbichler (2015) showed that US regions with a large variety of industries were more resilient to sector-specific shocks. Xiao et al. (2018) show that both related and unrelated variety exhibit a positive effect on regional resilience for EU regions, especially on the entry of knowledge-intensive industries after the shock. Duschl (2016) found that, for German regions, more unrelated variety in their industrial portfolio is associated with higher resilience. Both Sedita et al. (2017) and Cainelli et al. (2019a), using data for Italian regions, find that related variety matters for regional resilience.

In the second category, closest to our work, Eriksson and Hane-Weijman (2017) use Swedish data to show that cohesive (i.e., with many skill-related industries) and diverse (i.e., with a high degree of unrelated variety) regions are more resilient over time. Lazzeretti et al. (2019) similarly find the presence of related industries to be positively associated with resilience. Turning to the role of related occupations, Moro et al. (2021) find that occupational embeddedness is a significant predictor of resilience as measured by the peak unemployment rate during the recession in the US. Hane-Weijman et al. (2021) look at the occupational relatedness of industries entering and exiting a region, and argue that regions entering more related occupations experience faster employment growth, while finding that this effect is more pronounced before the financial crisis. Finally, turning to technological relatedness, Balland et al. (2015) showed that US regions with a high degree of relatedness to missing technologies fared better when faced with a shock. Using EU data, Cainelli et al. (2019b) find that technological and customer-supplier linkages both matter for the resilience of EU regions, and Rocchetta et al. (2020) find that EU regions endowed with technologically coherent capabilities adapted better in times of economic downturn.

The UK is well-known for economic imbalance and divergent growth paths across cities and regions (Gardiner et al., 2013; Martin et al., 2016), so much so that a key tenet of government policy surrounds the so-called 'Levelling Up' agenda (Tomaney and Pike, 2020). A recent body of work focuses on uncovering structural change across UK cities. In particular, examining 85 UK cities between 1971 and 2014, Tyler et al. (2017) investigates changing sectoral employment shares in northern vs southern cities, finding that the share of manufacturing has fallen in both groups but fastest in the north. Employment in public services in the north has caught up with the south, but employment in KIBS remains significantly lower. Overall, the authors observe structural convergence across cities over time, and a fall in the degree of sectoral specialisation.

A variety of recent papers have examined the drivers of regional resilience in the UK, similarly finding substantial differences across cities (Martin and Gardiner, 2019b). Kitsos and Bishop (2018) and Kitsos et al. (2019) suggest a significant role for initial economic conditions, human capital, age structure, urbanisation and geography and industrial embeddedness in local supply chains for (employment-related) resilience to the 2008 shock. Two recent, albeit conflicting as above, papers focus on the role of technological endowments in the resilience of UK cities. Rocchetta and Mina (2019) find that regions endowed with technologically coherent knowledge bases are better prepared to face an unforeseen downturn, while Bishop (2019) find - pointing in the opposite direction - that unrelated knowledge diversity and employment in knowledge intensive services is key to regional recovery from an economic shock.

Here we go beyond broad metrics of variety and coherence or relatedness, and focus on a specific channel - inter-industry mobility - as a key factor in labour market resilience and structural change. In order to study labour market mobility over time, we used the Annual Survey of Hours and Earnings dataset (ASHE) dataset which followed 1% of UK workers over a 20 year period (1997-2018). We find that the rate of job churn and inter-industry job switches starts to increase in 2009, and peaks in 2011 before slowly declining. By 2018, it had not returned to pre-crisis switching rates.

Next, we develop an empirical model to predict employment growth at the city-industry level based on the size of employment in related industries in a city. Our dataset is the Business Register and Employment Survey (BRES), which contains information on employment by city and industry between 2009-18. Our key predictive metric is termed 'related employment' in the literature, and uses a normalised measure of labour mobility between sectors in order to infer pairwise industry relatedness (Neffke and Henning, 2013a) (constructed using the ASHE dataset above). We find that employment growth is most strongly associated with related employment during the immediate post crisis recession period 2008-11. We interpret this result as suggesting that cities that can re-allocate workers into skill-related sectors fare better in terms of employment growth during the crisis period.

Finally, we investigate the rate of structural change of UK cities between 2005 and 2018. We find that the rate of change increased immediately post crisis, peaking in 2009 before declining quickly back to base rates by 2010.

2 Data

There are two key datasets for our analysis, the Annual Survey of Hours and Earnings (ONS (2019)) and the Business Register and Employment Survey (ONS (2017)).

We use the Annual Survey of Hours and Earnings dataset (ASHE), which is the most comprehensive source of earnings information in the United Kingdom, to track workers job history. This dataset contains anonymised demographic and employment information of 1% of the total employee jobs in the HM Revenue & Customs (HMRC) Pay As You Earn (PAYE) records, covering the years between 1997 to 2018. The sample is drawn in such a way that many of the same individuals are included from year to year, enabling us to conduct a longitudinal analysis of the data. For every worker, the dataset includes information on various variables, from individual characteristics, such as age and sex, to employment information, including pay, occupation and industry. The sample does not include the self-employed.

We use the Business Register and Employment Survey (BRES) for the years 2009-2018, as well as the Annual Business Inquiry (ABI) for the years 2007-2008, to measure employment. These databases contain employment records from all registered firms in the UK, and are compiled by the Office of National Statistics (ONS).

We analyze this data at two different geographical scales: regions, as given by the NUTS 1 classification, and functional urban areas (FUAs) as defined by the OECD. The BRES and ABI datasets provide aggregation to the NUTS 1 level, but to obtain the FUAs we aggregate the local authorities following the OECD definitions. There are 11 regions and 105 FUAs. We define industries using the 4 digit level standard industrial classification (SIC 2007).

There are 616 industries in SIC 2007, however, only for 440 of them do we find positive levels of employment throughout the main period of interest (2008-2017). Furthermore,

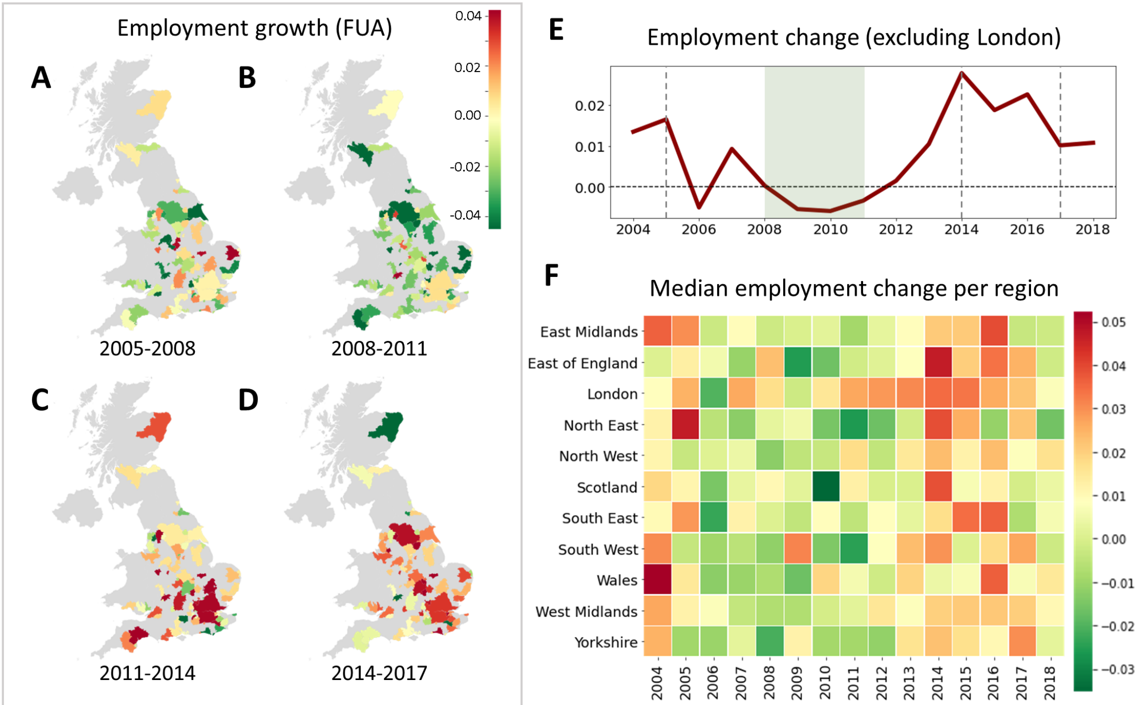

Figure 1: The geography of the 2008 financial crisis. [A-D] Cities (OECD functional urban areas) differ in the timing and persistence of the crisis. While in London employment contracts only for 2008-2009, other regions, like the North and South West, continue to lose jobs until 2011. [E] The evolution of the employment growth rate for the UK. [F] The evolution of the employment growth rate for UK cities aggregated by region.

since we our framework relies on the skill overlap between industries, we need to restrict ourselves to the industries that appear on the largest connected component of the skill relatedness network, leaving us 360 industries. This industries account for 75% of the total employment in the UK. The industries left out of the analysis belong mostly to agricultural, mining, gas and oil extraction and related sectors.

3 Methodology

Here we briefly introduce our approach to identifying recession and recovery periods from employment data, computing job churn and inter-industry switching metrics, our econometric setup to predict city-industry employment growth rates and our methodology for quantifying structural change of cities over time.

3.1 Identifying recession and recovery periods

Although there is no unique definition of recession, there is a general consensus that two or more consecutive quarters of negative economic growth can be considered a recession. Since we are working with annual employment data, we consider any year with negative employment growth to be a recession, and we will consider the recovery period to be the years following a recession up to the peak in employment growth. This approach corresponds to common frameworks used to model resilience, e.g., Fingleton et al. (2012). Following this methodology, we arrive at three distinct periods for our study:

- Pre-crisis: 2005-2008
- Recession: 2008-2011
- Recovery: 2011-2014
- Post-recover: 2014-2017

3.2 Job churn, inter-industry switching and skill-relatedness

We use the ASHE dataset to estimate the rate of job churn and switches (inter-industry switches) for each year. Each employment spell is recorded separately in the dataset, and hence we define a job transition to have occurred if a person has multiple entries with different employers in a year. We compute the job churn as the share of job transitions relative to total workers in the dataset per year. The switching rate is the number of job transitions that also switch industry code as a share of total workers per year.

We follow an established framework for estimating the skill similarity across industries (Neffke et al., 2011; Neffke and Henning, 2013a). By looking at the relative frequency of job transitions between industries, we are able to identify which industries are most similar in terms of their skill and knowledge requirements. This allows us to build a network where the nodes are the different industries and the edges weights are given by the skill relatedness. Following Neffke et al. (2017), for a pair of industries i and j, the skill relatedness is calculated by comparing the observed transitions to a null model (equivalent to a network configuration model). The null model is given by:

$$\hat{F}_{i,j}^{t,t+1} = \sum_j F_{i,j}^{t,t+1} \frac{\sum_i F_{i,j}^{t,t+1}}{\sum_i \sum_j F_{i,j}^{t,t+1}}$$

where $F_{i,j}^{t,t+1}$ is the number of observed transitions between industries i and j between time t and $t+1$. The first term of the right hand side sums all the transitions involving industry j and the second term calculates the fraction of all flows between industries

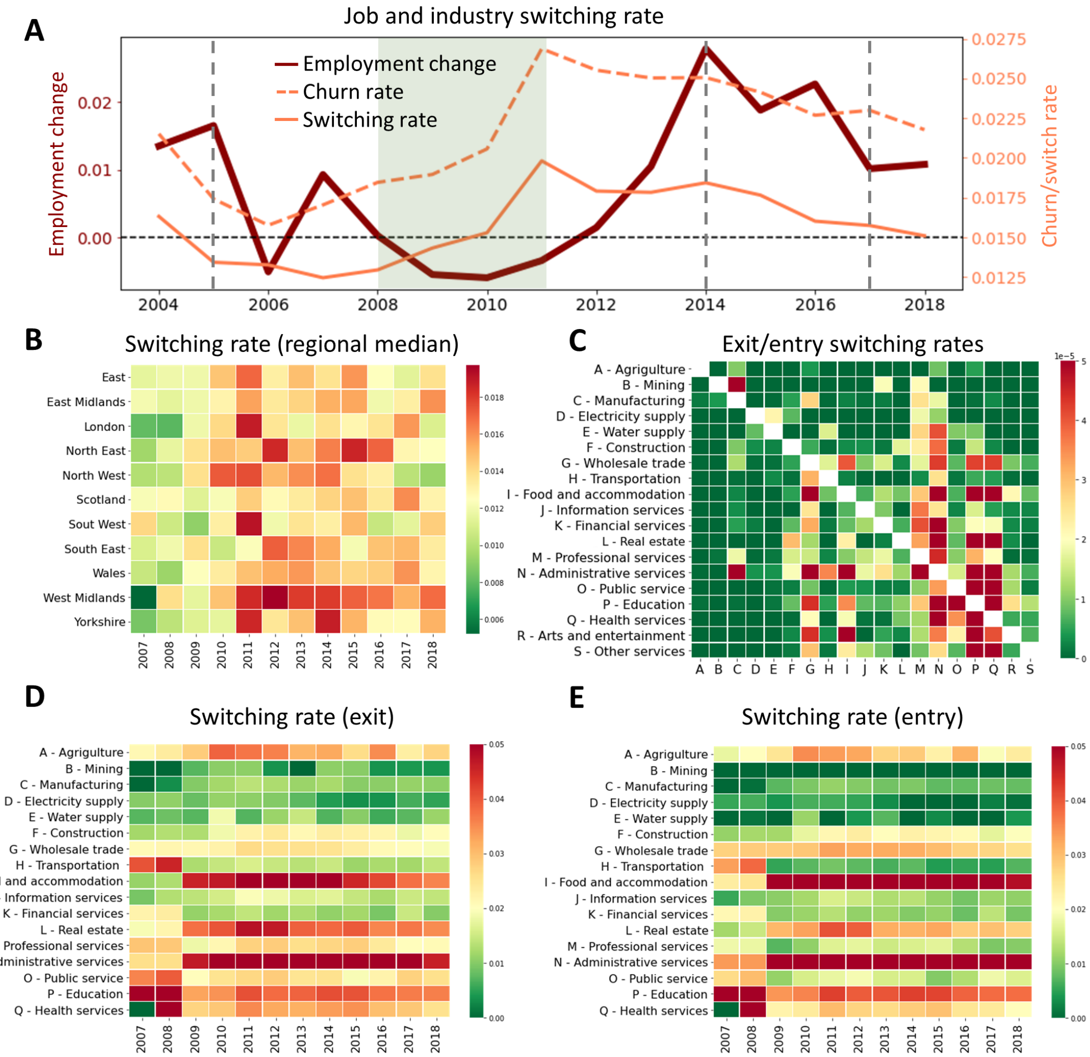

Figure 2: Switching. [A] The change in overall employment and the inter-industry switching rate. Notice that from 2008-2011, while employment change is negative, the switching rate increases rapidly, and starts cooling off after the end of the recovery period. [B] Switching rates by region. We can see that across regions, switching rates start low, peak around 2011, and slowly cool down after that. [C] Switching exit rates across industries for the period 2008-2017. The rate is with respect to the size of the original sector, meaning that rows with high rates (for example Administrative Services) have relatively many workers moving to other sectors; in general we find that services (including public service) have a much higher rate of switching than manufacturing, agriculture and other sectors. [D-E] Evolution of exit and entry rates for each sector across the period 2004-2018. Some sectors exhibit a large disparity between exit and entry rates; Mining has a much higher exit rate while Food and Accommodation enjoys a larger entry rate.

that involve industry i. We can think of $\hat{F}_{i,j}^{t,t+1}$ as the number of transitions that we would see between these industries if the flows were proportional to how frequently the industries appear across all transitions. The skill relatedness is then calculated as:

$$SR_{i,j}^{*} = \frac{F_{i,j}^{t,t+1}}{\hat{F}_{i,j}^{t,t+1}}.$$

If $SR^*_{i,j} > 1$, we observe more transitions than would be expected at random. We apply a transformation to map the relatedness symmetrically to $[-1, 1]$:

$$SR_{i,j} = \frac{SR_{i,j} - 1}{SR_{i,j} + 1}.$$

Finally, we only consider positive values of this quantity, that is, those that correspond to pairs with more transitions than would be expected at random.

We apply this methodology to job transitions from the ASHE dataset between 2009-18. The largest connected component of the resulting network contains 360 industries, which represent over 75% of the UK's total employment. Since we are interested in the relationship between skill-relatedness and resilience, we restrict our analysis below to this subset.

3.3 Econometric model

We build on a large and growing literature that focuses on the role of inter-industrial linkages in the economic growth of a region. It has been shown that industries grow faster in regions where there is substantial employment in skill-related industries (Neffke et al., 2011; Neffke and Henning, 2013a; O'Clery et al., 2016). Let E^t_{jr} be the employment in industry i in region r at time t, we can then calculate its related employment by

$$Rel^t_{ir} = \sum_j \frac{SR_{i,j} E^t_{jr}}{\sum_{k \neq i} SR_{i,j}}.$$

We estimate the effect of related employment on employment growth using the following equation:

$$G^{t_0,t_1}_{ir} = b_0 + b_1 \ln(E^{t_0}_{ir}) + b_2 \ln(Rel^{t_0}_{ir}) + I_i + R_r + \epsilon_{ir}$$

where G^{t_0,t_1}_{ir} is the logarithm of employment growth in industry i and region r during the period (t_0, t_1), $E^{t_0}_{ir}$ is the initial employment in the industry-region pair, $Rel^{t_0}_{ir}$ is the related employment in the industry-region pair at the start of the period, and I_i, R_r are industry and region fixed effects.

3.4 Structural change

Following Diodato and Weterings (2020) we compute the structural change of a city as the absolute value of the difference in employment shares across sectors. If D^t_{ir} is the share of employment in industry i in region r at time t, the structural change for region r between time t and $t+1$ is simply:

$$SC_r^{t,t+1} = \sum_i |D_{ir}^t - D_{ir}^{t+1}|$$

4 Results

In 2008 the UK entered a period of economic recession, driven by the 2007-2008 Financial Crisis. The extent of the recession varied significantly by geography, with northern and peripheral cities particularly hard hit. For our analysis we consider 4 distinct periods: the recession (2008-2011), the recovery (2011-2014) as well as the period immediately before the recession (2005-2008) and after the recovery (2014-2017). Figure 1 A-D illustrates how the employment growth varied across regions during these four periods. Although some peripheral city-regions to the North and West had negative growth rates pre-recession, most FUAs outside of London experienced negative employment growth rates during the recession period. By 2011 a strong recovery is evident, particularly in Southern and South-western cities.

The recession and recovery periods were identified by looking at the employment numbers in the UK. As shown in Figure 1 E, the recession period is made up of the years for which employment change in the UK (omitting London) is negative, while the recovery period includes subsequent years up to the peak in employment growth in 2014. Figure 1 F provides a more granular view, showing the mean employment growth rate for cities aggregated by NUTS region. We observe that while London saw a negative employment change for just a short period, 2009-2010, virtually every other region experienced a negative rate for at least another two years. Some areas, like the North East, maintained a negative rate until 2014, missing entirely the recovery period driving employment growth elsewhere.

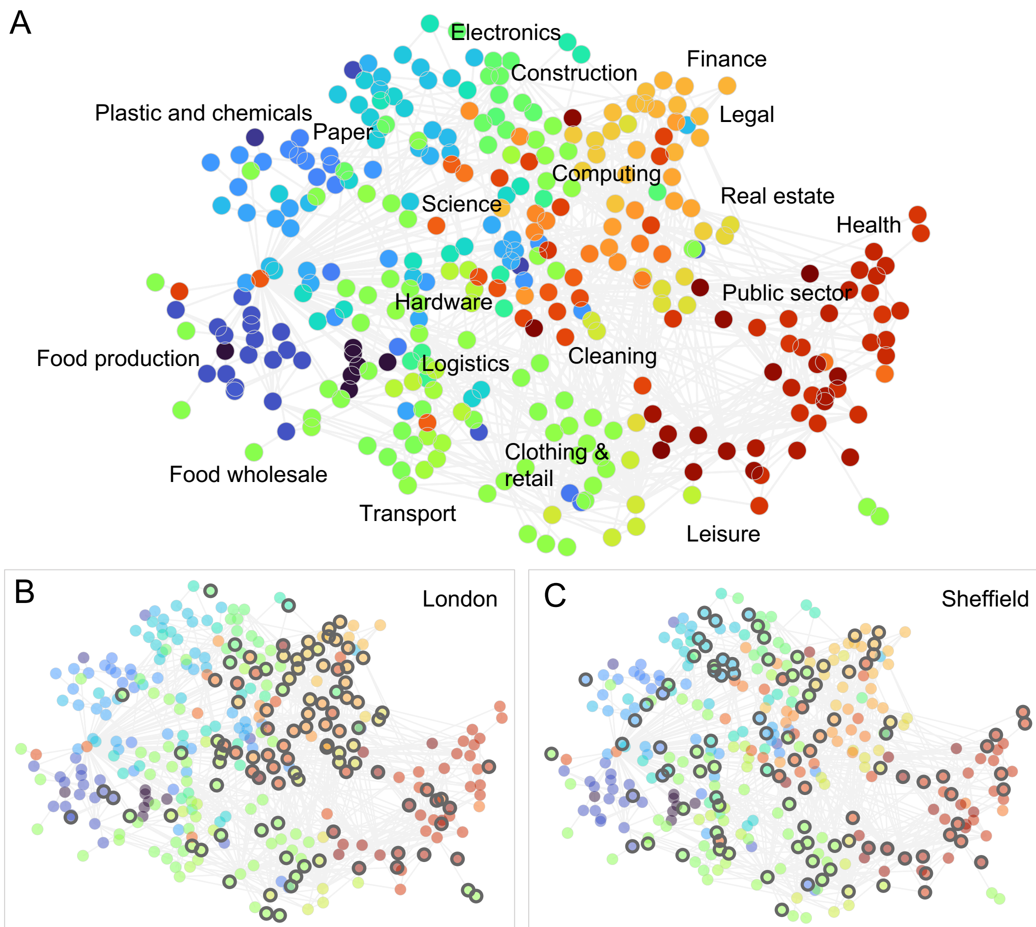

Figure 3: [A] Skill-relatedness network for the UK, with nodes coloured by 2 digit sector. [B-C] Industries with location quotient>1 highlighted for London and Sheffield.

Our key hypothesis is that cities with strong labour mobility linkages are more resilient to economic crisis as they can effectively re-allocate labour between sectors. Hence, first we investigate if the recession was a period of increased inter-industry labour mobility. Figure 2 A shows that both the rate of job churn and inter-industry switching began to increase in 2009 before peaking in 2011 and then slowly declined, although by 2018 neither had returned to pre-crisis levels. This increase in job churn and industry switching coincides with the toughest years of the recession. This pattern holds for cities in most regions, as shown in Figure 2 B. In particular, we note that inter-industry switching peaked for most regions in 2011, just as the national employment growth rate begins to turn positive. Nevertheless, we also identify some regions (particularly the West Midlands and the North East) that continue to experience high levels of industry switching during the recovery period (2011-2014). These are the same regions that exhibit the slowest recovery after the crisis.

The switching rate does not vary only across regions, but also across industries. Industry sectors are groups of industries that are considered to be similar. In the SIC07 classification, the 616 industries (at the 4-digit level) are grouped into 22 (2 digit) sectors. We identify industry switches that jump across industry sectors. That is, we focus on the switches for which the initial and final industry belong to different sectors. Restricting ourselves to the 360 industries present in the skill relatedness network, in Figure 2 C we visualise the switches in matrix form. Entry (i, j) represents the exit rate from industry i to industry j normalized by the number of workers in industry i. Darker red squares indicate larger switching rates between sectors (jumps go from rows to columns). Hence, rows with higher entries tend to have a larger share of workers move to other sectors. We observe that inter-sectoral switches occur mostly between service-related sectors. For example, workers from a large variety of service sectors jump into administration (column N), education (column P), and health (column Q). On the other hand, farming, manufacturing and other non-service sectors appear relatively isolated (as shown by a lack of red squares on their rows). Hence, it appears that skills in services are more transferable across broad industrial sectors, whereas workers in non-service sectors tend to move to more similar industries.

In order to study the labour mobility linkages between sectors (in a city) in our model below, we deploy a normalised inter-industry skill-relatedness score proposed by Neffke and Henning (2013a). In the literature, skill-relatedness has been deployed as a measure of skill-similarity derived from labour mobility data. Instead of using the raw number or rate of inter-industry job switches, this measure accounts for the size of the origin and destination sector (similar to a configuration model in the network literature). These scores can be visualised as a network where nodes are industries, and edge weights

A Pre-crisis 2005-2008

	(1)	(2)	(3)
logE	-0.261***		-0.271***
	(0.004)		(0.004)
logRel		0.003	0.109***
		(0.010)	(0.009)
N	24552	24552	24552
R2	0.22	0.11	0.23

B Recession 2008-2011

	(1)	(2)	(3)
logE	-0.258***		-0.267***
	(0.005)		(0.005)
logRel		0.043***	0.121***
		(0.010)	(0.009)
N	24293	24293	24293
R2	0.20	0.10	0.21

C Recovery 2011-2014

	(1)	(2)	(3)
logE	-0.232***		-0.238***
	(0.004)		(0.004)
logRel		-0.000	0.073***
		(0.009)	(0.008)
N	24568	24568	24568
R2	0.21	0.11	0.21

D Post-recovery 2014-2017

	(1)	(2)	(3)
logE	-0.219***		-0.226***
	(0.004)		(0.004)
logRel		0.016*	0.087***
		(0.008)	(0.008)
N	24989	24989	24989
R2	0.18	0.08	0.19

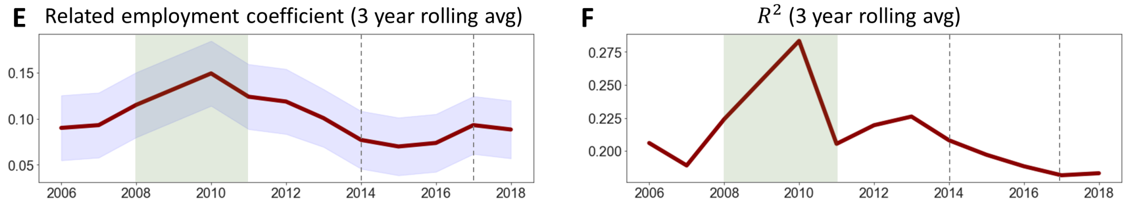

Figure 4: The role of related employment during the recession. We evaluate the strength of the relationship between employment change and relatedness by replicating the regression setup across the four periods we identified in our data: before the pre-crisis, recession, recovery and post-recovery. [A-D] The coefficient of related employment is larger during the recession than during the other three periods (at the p =0.05 level). [E-F] We extend the previous exercise by using rolling 3 year periods (i.e., for each year between 2006 and 2018 we fit the model using the previous three years). We can see that both the related employment coefficient and R^2 peak during the recession years.

correspond to the skill-relatedness score, see Figure 3. A force atlas algorithm has been used to generate an artistic representation of this high-dimensional data, and we can interpret the distance between nodes as an indication of their labour exchange.

We can think of cities as being 'located' in this network by considering the sub-graph of industries they are present in. The presence (or absence) of an industry is given by a location quotient (Balassa, 1965) (a metric that captures industry concentration, see Appendix A.2.1). In Figure 3 B-C, keeping the same underlying network structure, we highlight the nodes with location quotient greater than 1 for two major UK cities (London and Sheffield). We observe major differences in their industrial basket, meaning that each city has a distinct set of connections between both existing and related industries. Notice that in the case of London, the majority of the coloured nodes are surrounded by other coloured nodes, while in the case of Sheffield we see a sparser distribution of coloured nodes. Hence industries in London are better connected than those in Sheffield, providing workers with a wider range of similar industries in which their skills might be in demand. In general, both the composition of the industrial basket and its 'location' in the mobility network determine the potential for workers to re-allocate during an economic crisis.

The exploratory analysis we have presented above suggests that during the crisis, as the job market contracts, workers are more likely to look for employment outside their current industry. But they are unlikely to move into a random industry, instead they will look for opportunities in related industries (where related industries are those that have a high skill-relatedness score). Therefore, we expect that cities in which workers

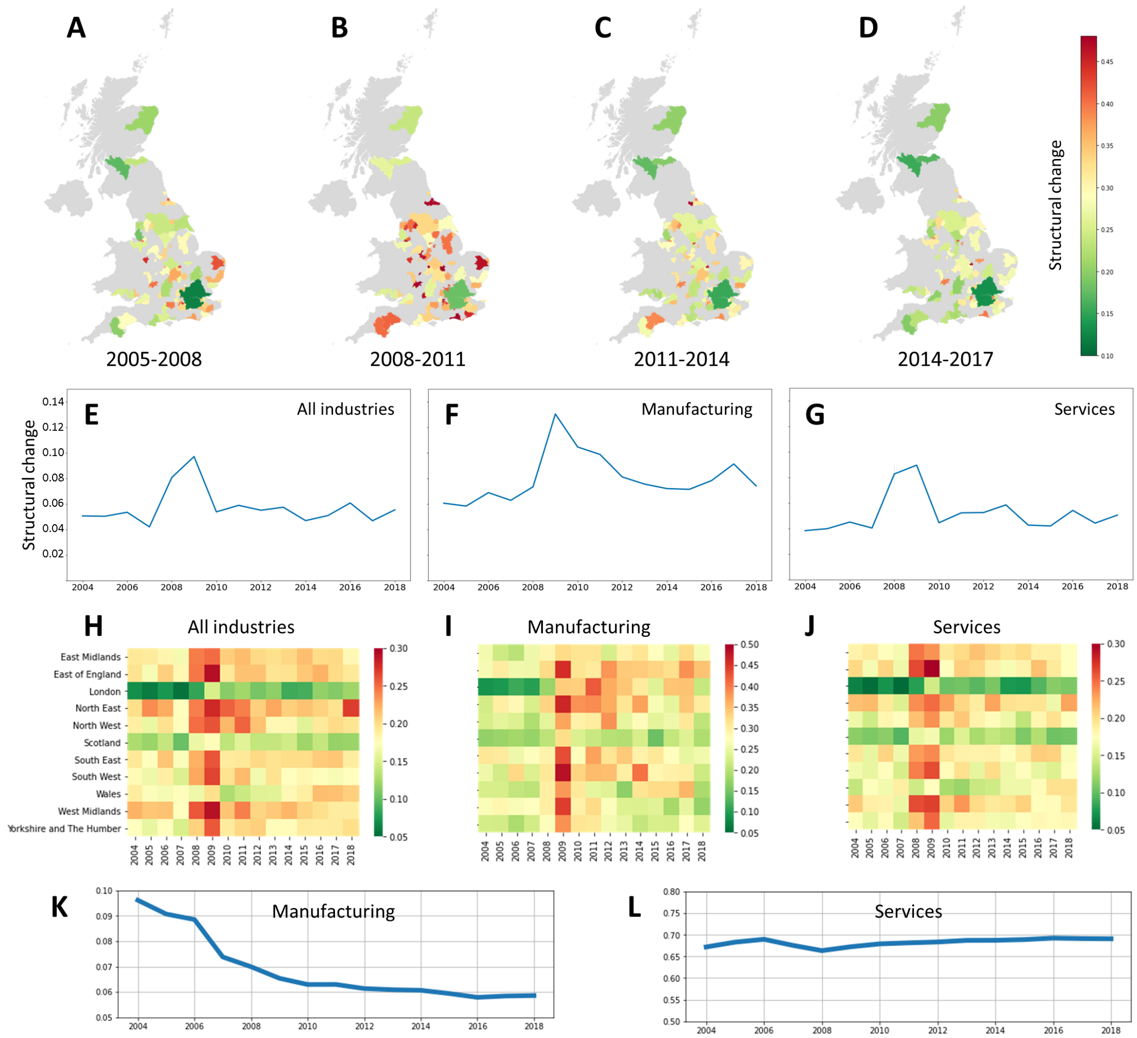

Figure 5: Structural change. [A-D] We compute the industrial change at the urban (FUA) level. Most of the structural change happens during the crisis period. [E-G] We measure the aggregate structural change during the period 2004-2018 for all industries, as well as for industries in manufacturing and services. In all three cases we see that structural change peaks between 2008 and 2011, but it is higher among manufacturing industries than it is among services. [H-J] We repeat the analysis but aggregate by region. London (and to a lesser degree Scotland) appears as an outlier, with very low levels of structural change. [K-L] The number of people in manufacturing industries has declined by close to 40% since 2004 (to just 6% of the working population), a decline that is particularly sharp in 2006-2008. The share of employment in services has remained stable just below 70% with a small dip in 2008.

have many similar industries into which they might move will be less affected by the crisis.

We implement our model to predict employment growth at the city-industry level based on the size of employment in related industries in a city (FUA). In Figure 4 A-D we see the result of regressing the logarithm of employment growth on the logarithm of initial employment plus the logarithm of related employment for each period of interest. We also include industry and city fixed effects. We find a significant positive effect of related employment on employment growth for each of the four periods. Importantly, the effect size is much larger during the recession period than during any of the other periods. Furthermore, the difference in magnitude of this coefficient between the crisis period and each of the other three is significant. In Figure 4 E-F, we repeat this analysis using a 3 year rolling window for employment growth, and observe a clear peak in the value of the coefficient and R2 during the recession period. We interpret these results as suggesting that employment growth in cities depends on key mobility linkages between industries particularly in a crisis.

Finally, we investigate the effect of the increased rate of industry switching during the crisis period on the industrial landscape. To this end, we measure structural change (at the FUA level) for the period 2005-2017. Figure 5 B shows that the majority of UK cities saw a large degree of structural turnover during the crisis period. The main exception is London, which sees low levels of structural turnover throughout this period.

We further disentangle by considering both manufacturing and services in isolation. Figure 5 F-G show that while both of them see structural change, particularly during the crisis, the rate at which the manufacturing sector changes is higher and more sustained than that of the services. This helps explain why London sees less turnover than the rest of the country, as it is heavily biased towards service industries.

Part of this story is no doubt an overall decline in manufacturing employment. As shown in Figure 5 K-L, while the share of employment in services remains stable just below 70%, with only a small dip during the peak of the crisis, manufacturing industries shrink, going from 9% of the workforce before the crisis to just 6% afterwards. So as employment grew in the recovery period, workers moved out of manufacturing and into services as part of a broader industrial re-organisation.

5 Discussion

We find that during the crisis (2008-2011) the rate of industry switching among the working population increased steadily, and that it remained high throughout the recovery period (2011-2014). This suggests that during a crisis, there is added pressure on workers to look for opportunities outside of their current industry.

While it is well established in the literature that related employment, which captures the size of employment in sectors connected by labour mobility linkages, is a strong predictor of employment growth, we show that in the UK this relationship is significantly stronger during the crisis period. This suggests that inter-industry labour mobility can help dampen the impact of an economic crisis.

The industrial switching that occurs during the crisis (and recovery period) translates into structural change: the industrial profile of the cities is transformed by the movement of workers out of some industries and into others. This connection between economic crisis, industry switching and structural change is an intuitive but novel one in the academic literature.

One of the main limitations of our work is the size of the longitudinal survey we use. The ASHE sample includes less than 1% of workers in the UK, meaning that labour mobility between industries is imperfectly measured. Furthermore, changes in the industrial classification (SIC03 to SIC07) means that care must be taken when comparing the rates of industry switches before and after 2008 (for example, if two closely related industries from SIC03 are merged in SIC07, we will see a drop in inter-industry switching without the underlying dynamics changing). Nevertheless, we do not observe a noticeable change in the overall switching and churn rates before and after the classification change, and we do not expect this change to significantly impact our analysis.

Another important limitation is that the period that our data covers, 1997-2018, only includes one crisis. Follow up work could include the downturn after the Covid pandemic to test the robustness of our findings.

While we have shown that related employment is significantly more important in predicting employment growth during the crisis than during other periods, and identified a potential mechanism behind it (the accelerated industry switching that results from job losses), we did not pursue, in this paper, an explicit identification strategy. Nevertheless, we believe that the relations highlighted can be interpreted causally. We note, in fact, that a global economic recession – which began in the United States' housing market and resulted in a stark drop in private and public demand worldwide – is an exogenous event, likely to be the root cause of the accelerated churn rates we observe. While differences in churn rates across regions may be influenced by complementary factors, the growth in churn rates in the crisis period is likely caused by the crisis and is not the cause of it. Likewise, with workers forced to move by the crisis, the accentuated importance of related employment appears to be a logical consequence of the circumstances surrounding the recession.

This is to say that – while careful validation exercises may improve the point estimate of the observed effect by discounting some potential alternative confounding factors – the exogeneity of the economic shock we study allows us to give causal interpretation to the results, if not in magnitude, at least in direction, thus reading our findings in temporal/logical sequence: shock -> more layoffs -> more inter-industry switching -> higher role for relatedness.

This causal interpretation suggests that cities with employment in sectors connected by strong labour mobility are better equipped to withstand a crisis and minimize unemployment. As this indicates a potential avenue for policy intervention – for instance through efforts to improve mobility between sectors through training schemes, job placements and other instruments – future research could focus on direct tests of the impact of these policies on the resilience of cities.

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A Appendix

A.1 Data

A.1.1 BRES

The Business Register and Employment Survey (BRES) is an employer survey of the number of jobs held by employees broken down by industry (5 digit SIC2007). The survey records a job at the location of an employees workplace. It is available from country down to lower level super output area. There are approximately 2 million businesses in the survey. The data is available from 2008, when it replaced the Annual Business Inquiry (ABI).

We also used the ABI to obtain employment numbers for the period 1997-2008, but under the SIC 2003 classification. The ONS has carried a matching exercise between both classifications for the years 2007-2008. This allowed us to link both periods.

A.1.2 ASHE

The Annual Survey of Hours and Earnings dataset (ASHE) is the most comprehensive source of earnings information in the United Kingdom. This dataset contains anonymised demographic and employment information of just under 1% of the total employee jobs in the HM Revenue Customs (HMRC) Pay As You Earn (PAYE) records, covering the years between 1997 to 2018.

Some of the available information in the dataset is the workers's wage, occupation, employment status, industry classification (5-digit level), location of their work establishment, etc. From 1997 to 2008 the data uses the Standard Industrial Classification from 2003 (SIC2003) whilst in the period from 2009 to 2018 the industrial classification has been updated to the 2007 version (SIC2007). As there is not a trivial concordance method for converting these codes, in the process of building the matrices the samples had to be treated separately into two parts, depending on the industrial classification available at the year of collection.

For the period of 1997-2008 we saw a total of 6947 individual transitions between 497 industries (representing 2.8% of non null values on the adjacency matrix). For the period of 2009-2018 we saw a total of 5141 individual transitions between 445 industries in the connections algorithms (representing 2.6% of non null values on the adjacency matrix). Using these 12,088 transitions we built the Skill-Relatedness network.

A.1.3 Skill relatedness network

Because of the non-trivial concordance between SIC 2007 and SIC 2003, we are restricted to the period 2009-2018 for calculating the skill-relatedness.

A.2 Methods

A.2.1 Location quotient

We use a location quotient to measure the degree to which a given industry is present in a particular city or region. The quotient is calculated as:

$$LQ_{ir}^{t} = \frac{E_{jr}^{t} / \sum_{j} E_{jr}^{t}}{\sum_{r'} E_{ir'}^{t} / \sum_{j,r'} E_{jr'}^{t}},$$

that is, the share of employment that industry i has in region r divided by the share of employment of industry i in the whole country.

A.3 Results

A.3.1 Robustness checks

The analysis was carried using the UK's SRN. This SRN was constructed using a sample of the working population, resulting in a sparser industry transition matrix than the ones constructed for other countries such as Germany or the Netherlands (Neffke and Henning (2013b)). While it has been shown that there is little variation between the SRN across countries (Neffke and Henning (2013b); Neffke et al. (2011)), there are important structural differences (Straulino et al. (2020)) that reflect the peculiarities of each country.

In order to validate our findings we replicate our analysis using the German SRN. The overlap between the German SRN and the industries with positive employment in the UK is smaller than when using the UK SRN. In this case we are restricted to 200 industries which represent about 60% of the jobs in the UK.

As in the main text, we consider three main periods, the recession, recovery and post-recovery periods. Tables **1-3** summarize the results of the corresponding regressions.

Just as in the original exercise, we observe that the coefficient corresponding to the effect of related employment is (significantly) larger during the crisis period than during either the recovery or post-recovery.

Table 1: 2008-2011

	(1)	(2)	(3)
logE	-0.313***		-0.322***
	(0.005)		(0.005)
logRel		0.012	0.183***
		(0.019)	(0.018)
N	19635	19635	19635
R^2	0.21	0.07	0.21

Table 2: 2011-2014

	(1)	(2)	(3)
logE	-0.255***		-0.262***
	(0.005)		(0.005)
logRel		0.007	0.143***
		(0.018)	(0.017)
N	19320	19320	19320
R^2	0.19	0.08	0.19

Table 3: 2014-2017

	(1)	(2)	(3)
logE	-0.238***		-0.245***
	(0.005)		(0.005)
logRel		0.013	0.142***
		(0.017)	(0.016)
N	19320	19320	19320
R^2	0.19	0.07	0.19

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