

Examining factors that can alleviate labour shortages

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Grant agreement no. 101132581

Deliverable: D5.10 Paper migration

Due date: 30.09.2026



**Funded by
the European Union**

Document control sheet

Project Number:	101132581
Project Acronym:	SkiLMeeT
Work-Package:	5
Last Version:	30.09.2026
Issue Date:	30.09.2026

Classification

Draft	
Final	x
Confidential	
Restricted	
Public	x

Legal notice

This project has received funding from the European Union's Horizon 2022 Research and Innovation programme under grant agreement No. 101132581. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the granting authority can be held responsible for them.

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Abstract

This report uses Luxembourg as a case study to examine the factors that may help alleviate labour shortages, given its strong reliance on cross-border workers. To this end, we have combined data from the European Labour Force Survey (EU-LFS) and the European Union Statistics on Income and Living Conditions (EU-SILC), both of which are provided by Eurostat, as well as data from the European Working Conditions Survey (EWCS) from Eurofound. Our analysis is based on the occupational labour shortage indicator developed in SkiLMeeT Tasks 2.3 and 3.4. First, we analyse labour market outcomes related to labour shortages, including new hires and unemployment, using EU-LFS data. We then construct a range of potential drivers of labour shortages, including wages (EU-SILC), usual working hours, employment growth, workforce composition and working conditions. Using EU-LFS data, we derive occupation-level indicators at the ISCO 3-digit level, including: (i) the distribution of workers by residential status and region of origin (native residents; EU-15 residents; non-EU-15 European residents; and cross-border workers from France, Belgium and Germany); (ii) the share of women; (iii) the age distribution of workers in 10-year age groups; and (iv) the share of part-time workers. To account for job quality, we complement these indicators with occupation-level measures of working conditions derived from the European Working Conditions Survey (EWCS).

Our main findings are the following. The response to labour shortages differs across worker groups and over time. In most cases, the response of a given group following the emergence of a labour shortage occurs either at $t+1$ or at $t+2$, rather than at both horizons, pointing to group-specific adjustment mechanisms operating with different lags. A further examination of the different worker groups considered in the analysis—French, Belgian and German cross-border (CB) workers, natives, EU15 and European non-EU15 workers—is consistent with a hierarchy of labour-market adjustment mechanisms. Factors such as the size of the available labour pool, differences in wage demands or reservation wages, and language proximity may facilitate a relatively rapid response by some groups. Groups that benefit less from these advantages appear to respond to labour shortages with a longer delay. Occupational specialisation in the region of residence may, however, partly compensate for such disadvantages by increasing the availability of workers with the qualifications required in shortage occupations.

The results also show that the intensity of labour shortage matters for the composition of the adjustment. Among French, Belgian and German CB workers and natives, no two groups display exactly the same combination of response timing and shortage intensity, the hiring of natives being the most focus at high labour shortage. This heterogeneity could suggest that employers draw on different labour pools at different stages and intensities of labour shortage and then that the adjustments do not depend only to labour supply. It may also be consistent with a role for the institutional and policy framework in shaping these adjustment possibilities. Further analyses would be required to identify potential mechanisms supporting them. Finally, most of the covariates that help account for the relationship between shortage intensity and the response of a particular worker group appear to be group-specific. Further analysis is therefore also required to identify whether common mechanisms operate across groups and, ultimately, which factors could provide broader opportunities for alleviating labour shortages.

Keywords: Labour shortage intensity, occupational labour markets, cross borders workers, worker heterogeneity, labour market adjustments.

Acknowledgements:

We would like to express our gratitude to Ronald Bachmann, Julia Bredtmann and Serife Yasar (RWI) for guidance in structuring the empirical design and their assistance with the literature review. Any remaining shortcomings or errors remain our own responsibility.

1 Introduction

Labour shortages have become a significant challenge for many European labour markets, with major implications for economic growth, productivity and the provision of essential services. Luxembourg is a particularly relevant case study in this regard, given its heavy reliance on cross-border (CB) workers, who make up a significant proportion of its workforce. Therefore, understanding the factors associated with labour shortages in this context can provide valuable insights for national and European policymakers.

This report aims to identify occupational characteristics that could help alleviate labour shortages in Luxembourg. To this end, we have combined data from the European Labour Force Survey (EU-LFS) and the European Union Statistics on Income and Living Conditions (EU-SILC), both of which are provided by Eurostat, with data from the European Working Conditions Survey (EWCS), which are provided by Eurofound. This integrated dataset allows us to examine a wide variety of labour market outcomes and occupation-level characteristics that could influence labour shortages.

Our analysis is based on the occupational labour shortage and explanatory mainly developed in SkiLMeeT Tasks 2.3 and 3.4. First, we analyse labour market outcomes related to labour shortages, including new hires and unemployment, using EU-LFS data. We then construct a comprehensive set of potential drivers of labour shortages, including wages (EU-SILC), usual working hours, employment growth, workforce composition and working conditions. Based on these variables, we examine the potential relationship between labour shortage intensity and coming growth of different workers groups (CB workers from France, Belgium, Germany, natives, EU15 residents, European non-EU15 residents) assuming potential delays and varying adjustments between the groups.

The remainder of this report is organised as follows. Section 2 describes the related literature. Section 3 presents data sources and how the occupation-level indicators were constructed. Section 4 presents the empirical analysis, including the models set-up for the labour shortage analysis. Finally, Section 5 discusses the main findings, their limitations and potential extensions and the policy implications.

2 Related literature

2.1 Measure of labour shortage

At the European level, labour shortages have become a key policy issue, as reflected in reports published by the European Commission (European Commission, 2021; McGrath, 2020, 2019), Eurofound and Cedefop (2020), the OECD (Causa et al., 2022) and several national analyses such as DARES in France by Grobon et al. (2022) or in Luxembourg by Martin and Baer (2022). These studies consistently highlight that labour shortages can constrain productivity growth, innovation and the green and digital transitions, thereby limiting long-term economic performance.

The labour shortage measure derived from McGrath (2020, 2019), that we use in this report, relates hiring to those who are unemployed and have previous experience in the occupation. While this approach is considered restrictive, experimental evidence from the United Kingdom, Belot et al. (2019), suggests that job seekers tend to restrict their search to occupations in which they already have experience, despite possessing transferable skills that could be valuable in other roles. This limited occupational mobility reduces the pool of potential applicants and can exacerbate shortages in occupations experiencing growing demand. Even when suitable jobs and workers coexist, imperfect information and search frictions can hinder efficient matching.

Recent European monitoring has broadened the set of indicators used to identify labour shortages. The European Labour Authority (2026) combines national information on shortage and surplus occupations with a quantitative indicator that compares vacancies, as a proxy for unmet labour demand, with unemployed workers, as a proxy for potential labour supply, at the ISCO 2-digit level; including the potentially active can materially change the resulting classification. Complementarily, Eurofound (2024) emphasises labour market slack, which also includes underemployed part-time workers and people who are available for work but not actively searching. Together, these approaches illustrate that measured shortages depend on how potential labour supply is defined and support the use of several complementary indicators.

2.2 Drivers of labour shortage

The literature identifies several mechanisms through which labour shortages emerge and persist. While skill shortages are often emphasised, recruitment difficulties also depend on labour mobility, wages and working conditions, and demographic characteristics.

2.2.1 Labour mobility

2.2.1.1 Migrants

In response to persistent labour shortages, many European countries have become increasingly reliant on migrants to fill vacancies in shortage occupations, making labour migration an essential policy tool for filling positions that cannot easily be filled by the domestic workforce (Anderson & Ruhs, 2012; OECD, 2025). However, the spatial adjustment of labour supply is often constrained by structural frictions, such as geographical distance (Docquier et al., 2014), linguistic or cultural barriers (Belot & Ederveen, 2012; Bredtmann et al., 2020), rigidities in the housing market (Mohino & Ureña, 2020), and institutional barriers, including restrictive visa policies and work permits tied to a specific employer (Bertoli & Fernández-Huertas Moraga, 2015; de la Rica et al., 2015).

Even when migration occurs, the ultimate contribution of migrants depends not only on their labour market participation, with notable employment gaps relative to natives remaining across European host countries (Frattini & Dalmonte, 2024; Dustmann et al., 2026), but also on how effectively their skills are utilised. Research consistently demonstrates that migrants experience higher rates of skill mismatch and overeducation than native workers (Jestl et al., 2015; Visintin et al., 2015). Most recently, findings from the 8th Migration Observatory Report underscore that, despite approximately one-third of first-generation immigrants in Europe possessing a tertiary degree (a proportion nearly equivalent to EU nationals), foreign-educated tertiary migrants face significant overeducation gaps of approximately 20 percentage points for EU origins and 24 percentage points for non-EU origins relative to comparable natives (Frattini & Dalmonte, 2024). This mismatch results in acute occupational downgrading, whereby highly educated non-EU foreign-qualified migrants are more likely to work in elementary occupations and less likely to secure high-skilled professional roles than native peers with identical qualifications. While this penalty varies geographically, utilising migrants' existing skills more effectively could help reduce labour shortages without necessarily expanding the overall labour supply.

A primary cause of this skill mismatch lies in the imperfect cross-border transferability of foreign human capital combined with institutional barriers to credential recognition (Chiswick & Miller, 2009). Historically, these institutional hurdles have been compounded by a persistent lack of consensus on adopting a common competence model despite initiatives such as the European Qualifications Framework (Winterton, 2009; Barslund & Busse, 2014). As Anger et al. (2024) demonstrate, eliminating administrative barriers to credential recognition can yield substantial benefits in terms of official

qualification recognition, increased employment of migrants in regulated professions and reduced migrant-native wage gaps.

2.2.1.2 Cross-border workers

In the context of integrated cross-border labour markets, CB workers play a key role in alleviating labour shortages by increasing the available labour supply beyond national borders (Heinz & Ward-Warmedinger, 2006). This is particularly relevant in regions characterised by strong economic integration and significant wage differentials between neighbouring countries. Within the European Union, cross-border commuting has been a regular occurrence since the early twentieth century (Knotter, 2003), facilitated by the progressive removal of border barriers and cross-border cooperation. The largest cross-border flows in absolute terms are those from France, Belgium, and Germany to Luxembourg, while Switzerland receives an even greater total number of CB workers, though these are relatively less dominant within its broader domestic market. Other notable cross-border labour markets include the Øresund region between Denmark and Sweden, the Estonia–Finland border, and the Austrian borders with the Czech Republic, Hungary and Slovakia, although their volumes remain considerably lower than those around Luxembourg (Tsiopa et al., 2024).

With respect to the individual determinants of cross-border mobility, previous evidence indicates that CB workers tend to be more highly educated (Hansen & Nahrstedt, 2000; Huber, 2014), younger (Huber & Nowotny, 2013; Huber, 2014), and predominantly male, which is partly due to domestic production demands and higher rates of part-time employment among women (Gottholmseder & Theurl, 2007). Regarding education, recent evidence from Luxembourg reveals a pattern of skill polarisation. Analysing administrative transition data, Albanese & Marguerit (2022) reveal a U-shaped relationship, showing that workers at both ends of the skill spectrum have the highest propensity to commute. This creates a 'gap in the middle' that reflects Luxembourg's specific demand for low-skilled service roles and high-skilled specialised positions.

At the macroeconomic level, empirical studies identify wage differentials as a push and a pull factor for cross-border commuting (Broersma et al., 2022; Edzes et al., 2022), while regional unemployment serves as an important push factor (Mathä & Wintr, 2009; Broersma et al., 2022). While cross-border labour mobility can act as a regional adjustment mechanism by enlarging the effective labour supply in receiving regions and reducing unemployment in origin regions (Pierrard, 2008; Illing, 2025) and improving spatial skill allocation, it can also have adverse effects on native workers. Evaluating a 1991 German-Czech commuter allowance, Dustmann et al. (2017, 2025) show that the resulting inflow of

Czech workers to German border regions led to a moderate decline in average local wages and a sharp decline in the local native employment. However, broader empirical evidence reveals that host labour markets can successfully absorb CB workers without harming native incumbents when conditions allow. Evaluating the 2011 EU freedom-of-movement expansion, Illing (2025) finds that native incumbents in German border regions experienced no job losses or wage cuts, as host firms primarily adjusted by reducing new native hiring and entry-level wages, rather than displacing existing staff. Similarly, examining the implementation of free movement in Switzerland, Beerli et al. (2021) show that cross-border inflows supported firm-level expansion and skill allocation without triggering native job displacement.

2.2.2 Wages and working conditions

Some more recent evidence suggests that labour shortages cannot be explained by a simple lack of skills. Using data from the Second European Skills and Jobs Survey, Cedefop (2024) highlights that the causes of labour shortages vary significantly across different occupations. While some labour shortages are associated with high skill requirements, others are primarily related to poor job quality, unattractive working conditions, high labour turnover or limited geographical mobility. This challenges the view that labour shortages are simply the result of skill deficits, highlighting the importance of considering wages, working conditions and other job characteristics when analysing occupational labour shortages.

One possible explanation relates to the attractiveness of jobs, particularly in terms of wages and working conditions. According to standard economic theory, labour shortages should be less frequent in occupations offering more attractive compensation, since higher wages increase the labour supply and improve recruitment. Empirical evidence supports this prediction. For instance, using UK data, (Haskel and Martin, 2001) reveal that firms paying higher average wages encounter fewer difficulties when recruiting than comparable firms offering lower pay. However, wages are only one aspect of job attractiveness. Eurofound and Cedefop (2020), and Cedefop (2024), argue that poor working conditions, limited career prospects, demanding work schedules and an insufficient work-life balance can discourage workers from entering or remaining in certain occupations. This can contribute to persistent labour shortages. Among the occupations that do not require a university degree, Hauret and Martin (2023) provide a comparison of working conditions between occupations in shortage and similar occupations that are not in shortage. The exploratory analysis, carried out across the Greater Region

results do not indicate that pay conditions are worse in shortage occupations. However, it highlights less favourable working conditions in shortage occupations for six of the eight aspects examined (appropriate pay, health and safety at work, job security, working atmosphere, training and work-life balance). In the same vein, Coutrot (2022) reveals that in 2019, recruitment difficulties were highly prevalent among French employers whose workers faced difficult working conditions. Unusual or unpredictable working hours, as well as the difficulty in producing high-quality work, were the occupational exposures the most closely associated with recruitment difficulties.

These findings suggest that improving job quality may be as important as increasing wages in addressing labour shortages. Recent evidence reinforces the role of job attractiveness and retention. Eurofound (2024) reports that employers facing recruitment and retention problems increasingly use higher pay, non-wage benefits and improvements in working conditions, including more flexible working time and remote work, to make vacancies more attractive. For Germany, Bachmann and Heinze (2025) analyse occupational inflows into and outflows from shortage occupations using administrative employment data combined with information on wages and job satisfaction, highlighting those alleviating shortages requires both attracting workers and reducing exits. More generally, Bachmann et al. (2025) show that voluntary job and occupational mobility is associated with gains in earnings and job satisfaction, suggesting that workers outside options can reinforce recruitment and retention problems in less attractive occupations. Consistent with this, Cedefop (2026) identifies low pay, strenuous working conditions and low job attractiveness as important drivers of persistent shortages in vocational occupations.

2.2.3 Demographic characteristics

Demographic change has become an important factor in determining labour supply. Population ageing reduces indeed the number of workers entering the labour market, while increasing the demand for health and long-term care occupations (Brunello & Wruuck, 2021).

Occupational gender segregation also plays a role. Blau and Kahn (2017) and OECD (2023), highlight that labour shortages are often concentrated in highly gender-segregated occupations such as healthcare, social care, construction, and ICT. There is also increasing evidence that demographic pressures and the mobilisation of underrepresented groups are becoming increasingly important. The European Commission (2025) identifies women, older persons and migrants as the main groups outside the EU labour force and stresses that increasing their participation can help alleviate labour shortages.

Cedefop (2026) finds that ageing workforces create pronounced replacement needs in shortage occupations and identifies gender segregation as a further factor limiting the available labour pool. Similarly, the European Labour Authority (2026) reports that women are under-represented in widespread shortage occupations, while older workers are over-represented in both shortage and surplus occupations, pointing to sizeable future replacement demand. Evidence for Germany also suggests that the future supply pipeline may reinforce shortages in occupations needed for the green transition: Bachmann et al. (2026) document declining numbers of MINT students and trainees alongside shortages in technical occupations such as mechatronics, automation and energy technology.

Existing literature suggests that labour shortages are caused by a combination of factors. Consequently, understanding labour shortages requires examining a broad set of occupation-level characteristics, including wages, working conditions, workforce composition, demographic structure and labour mobility. This report presents an empirical analysis that examines the association between these occupational characteristics and labour shortages in Luxembourg, informed by this enlarged perspective. This is done by splitting the working population by groups of workers and examining whether these groups respond to labour shortage quickly or with some delays, controlling for the factors detailed above.

3 Methodology and data

3.1 Labour Shortages

As previously outlined in SkiLMeeT deliverable 2.3 (Martin, 2025), we employ the approach adopted by McGrath (2021, 2020, 2019) and McGrath and Behan (2017), as well as that employed by Bachmann et al. (2023). This method involves calculating a shortage/surplus ratio for each occupation (ISCO 3-digit) that is suitable for the Labour Force Survey (LFS). The calculation is as follows: (number of recruits to the occupation in the year under review) / (number of inactive persons with previous work experience in this occupation in the year under review).

In the case of Luxembourg, to cover both the resident population and CB workers, we first combine the Luxembourg LFS with extracts of CB workers from the cross-border regions of France (Lorraine), Belgium (Luxembourg, Liège and Namur provinces) and Germany (Rhineland-Palatinate and Saarland).

In addition, we correct the labour shortage measurement, based on official statistics, by assuming a share of unemployed among the CB workers. More details are provided in the empirical part (4.1).

Second, to ensure that the newly constructed samples from 2012 to 2019 are representative of the Luxembourgish working population, we combine United Nations and Eurostat data with national data from the IGSS. Specifically, we use 2015 United Nations migration data and 2014 Eurostat values to reweight the LFS residents from 2012 to 2016 and 2019 United Nations migration data and 2019 Eurostat values to reweight the LFS residents from 2017 to 2019. To ensure the representativeness of CB workers as recorded in official data, we also use official figures from the IGSS (Inspection Générale de la Sécurité Sociale/General Inspectorate of Social Security) to reweight the LFS samples.

We use weight calibration procedures based on iterative proportional fitting, also known as 'raking', as outlined by Deville et al. (1993), to adjust the final sample for differences in the demographic composition between our samples and the actual populations in Luxembourg. In short, the procedure involves post-stratification adjustment of the population using three categorical variables (control variables: gender; residential situation and region of origin (native residents; EU15 residents; European non-EU15 residents; CB workers from Germany, vs Belgium or France; and age (below 30 years old; 30-39 years old; 40-49 years old; 50-59 years old; 60-67 years old)). These variables are available for both the population and the samples.

The procedure was implemented in Stata by Kolenikov (2014) as the Stata package 'ipfraking'. We are using this package to generate population weights for LFS data based on three common control variables.

For cross border regions, we also calculated the labour shortage on recalibrated samples using combined figures from United Nations and Eurostat data.

3.2 Explanatory variables

3.2.1 Hourly wages, usual number of hours worked per week, employment growth

Building on the methodology developed for the SkiLMeeT Deliverable 3.4 datasets (Martin and Burzynski, 2026), which covered hourly wages, usual weekly working hours, and employment growth, we used EU-SILC data (ISCO 2-digit level, for wage indicators only) and Labour Force Survey (LFS) data (ISCO 3-digit level) to enrich the labour shortage dataset with these variables.

To provide more detailed information on wage distributions, we also computed gender-specific wage quartiles for Luxembourg and its three neighbouring cross-border countries.

3.2.2 Working conditions

We used data from the European Working Conditions Survey (EWCS), conducted by Eurofound in 2010 and 2015, to incorporate occupation-level working conditions into the dataset. These indicators were computed at the ISCO 2-digit level and capture the working conditions experienced by employees within each occupation. To resume these indicators, a factorial analysis was run on the 2015 wave, leading to the creation of four main working condition factors.

3.2.3 Demographic characteristics

Using Labour Force Survey (LFS) data, we constructed four sets of occupation-level indicators at the ISCO 3-digit level: (i) the distribution of workers by residential status and region of origin (native residents, EU-15 residents, non-EU-15 European residents, and CB workers from Germany, Belgium, and France); (ii) the share of women in each occupation; (iii) the distribution of workers across age groups (under 25, 25-34, 35-44, 45-54, and 55 years or older); and (iv) the share of part-time workers in each occupation.

4 Results

4.1 Exploratory descriptive analysis of the labour shortage variable

The set-up of the labour shortage variable, in line with the description highlighted above (3.1), has led to treating some missing values in both the numerator and the denominator, even if these missing values are relatively limited. Indeed, our strategy based on the aggregation of all the information at the 3-digit ISCO level leads to a reduction in the number of observations likely to affect the strength of our empirical evidence. We recorded as missing values 62/811 observations (0.076) for unemployment and 7/811 (0.008) for new employment. We test different specifications to impute these missing values and select a Gaussian log model using lead values when there are available. Among the lead values, we select the most recent available, e.g. t-1 instead of t-2, and limit the leads used to t-4. Other imputation methods tested were OLS, Gamma-log basic, Gaussian-log basic, Gaussian-log with lead, Gaussian-log with lag and lead. All the models were compared on the basis of their 'Mean Absolute Error' and 'Root

Mean Squared Error'. A very simple selection of variables was used to conduct the imputations. The key variables used were the number of employees, the lag value of the dependent variable and two fixed effects, i.e. year and ISCO 2-digit level. The strategy was not to introduce in the imputation potentially relevant variables for further analyses, affecting, as such, their exogeneity in these further analyses. In addition, as our model will focus on upcoming employment growth of specific groups of workers, lead values were excluded from our imputations. A second issue would have been to compute the labour shortage variable using only the unemployment recorded by the Luxembourg authorities, and based only on the workers living in Luxembourg, and then excluding the CB workers while they were included in the numerator based on new employment. Doing so would have underestimated the labour shortage measurement applying to the Luxembourgish labour market. As no official measurement of unemployment was to our knowledge available for the CB workers, we assumed that share of unemployed was similar among them than among the resident population.

The distribution of the resulting labour shortage variable was examined, showing, among other things, a relatively high right tail (see tab 1) that may be due to measurement errors in the variables used for its computation at the 3-digit level. As an alternative, we have computed a revised measure of labour shortage based on the fitted values of unemployment, using the specification of the model used just above for the imputation of missing values. The revised measure shows a close median value (0.664 instead of 0.760), but a lower mean value and a lower skewness, in addition to a lower maximum (6.258 instead of 2.592).

Table 1. Descriptive statistics regarding the original and the revised measure of labour shortage

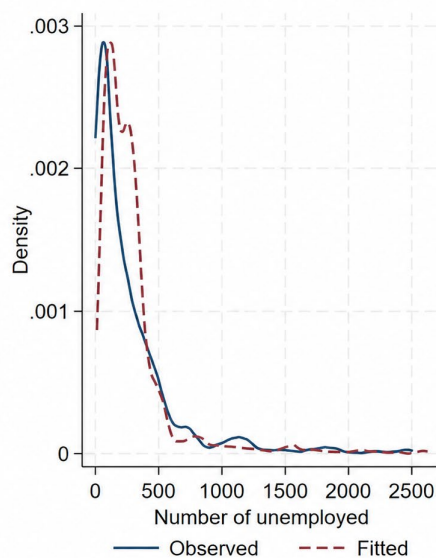
Shortage measure	N	Mean (SD)	Median [P25–P75]	P90	P95	P99	Maximum	Skewness
Original measure	811	1.529 (2.538)	0.760 [0.419–1.514]	3.576	5.276	12.335	28.927	5.34
Revised measure	811	0.885 (0.813)	0.664 [0.346–1.134]	1.786	2.372	4.311	6.258	2.5

Source: EU-LFS datasets 2013 to 2019. The sample is restricted to Luxembourg. Aggregation at ISCO 3-digit level were carried out.

Different tests were run to validate this revised measure. The results showed a strong correlation between fitted and observed values and a small bias. The R^2 between fitted and observed with year and ISCO 1-digit fixed effects was indeed rather high ($R^2=0.85$). In addition, the mean error corresponding to the gap between the fitted and observed data is only 15.2 workers, corresponding to 0.10 standard deviations of the prediction errors, suggesting a modest average bias. Finally, the kernel distribution of the fitted unemployment count was very close to the original distribution (see Figure

1). Both are strongly concentrated at low counts and have a long right tail. The fitted curve peaks slightly to the right of the observed curve and was smoother, with fewer of the small secondary bumps visible in the observed data. The main difference was therefore that the fitted distribution is somewhat smoother and shifted towards higher counts near the peak.

Figure 1. Kernel density distribution of observed and fitted number of unemployed



Source: EU-LFS datasets 2013 to 2019. The sample is restricted to Luxembourg. Aggregation at ISCO 3-digit level were carried out.

To complete this explanatory analysis, we have produced different graphs aiming at examining the potential relationship between the share of workers in any given group of workers and labour shortage intensity. Does any relationship hold? Could these effects be non-linear, e.g., with specific variations at different labour shortage levels? The graphs carried out were dedicated to providing first insights regarding these questions.

In practice, we have examined the potential relationship between growth of a given group of workers (Y) in $t+1$ or $t+2$ and labour shortage intensity (X), assuming that labour shortage intensity may affect, with varying delays, the hiring of group of workers, as these hirings could reduce labour shortage. This exam was carried out on both the full distribution of the labour shortage values and with shortage values higher than 0.99, where labour shortage is really assumed to be at play.

The graphical result has highlighted, as expected, a potential discontinuity around 0.99, in line with the latter assumption. The graphical results have suggested in addition that potential non-linear

relationships may apply with U-shaped or inverted U-shaped. All this stressed the need for a specific model set-up, detailed later.

(See appendix A for the graphs).

To confirm the graph suggestions, we have computed employment growth by decile of labour shortage. These graphs confirmed that some non-linearities were at play.

(See appendix B for the graphs).

4.2 Model set-up

To adjust the model for the full range of labour shortage values, i.e. including values lower than 0.99, we have generated the following two variables: `shortage_regime` and `S_above`. `S_above` focuses simply on the theoretical values where labour shortage may matter i.e. values greater than 0.99, while `shortage_regime` is dedicated to not excluding from the analysis observations with labour shortage below 0.99. The `shortage_regime` variable provides, in addition, the opportunity to make the distinction between “smooth activation” and “regime activation”. According to the first one, once shortage exceeds the threshold (0.99 in our case), the adjustment gradually becomes stronger as shortage intensifies. According to the second one, simply entering the shortage regime (still 0.99) produces an immediate change, over and above subsequent intensity. `Shortage_regime` and `S_above` are defined as follow:

$$\text{Shortage_regime}_{it} = \begin{cases} 0 & \text{if } \text{labour_short} < 0.99 \\ 1 & \text{if } \text{labour_short} \geq 0.99 \end{cases}$$

$$S_above = \begin{cases} 0 & \text{if } \text{lab_short} \leq .99 \\ \text{lab_short} - .99 & \text{if } \text{lab_short} > .99 \end{cases}$$

To consider a potential non-linearity, with some U-shaped or inverted U-shaped response to labour shortage, we have included in addition `S_above^2` computed as the square of `S_above`. The different groups of workers may indeed respond in different ways to varying labour shortage intensity.

The time dimension may also not be neutral. Firstly, some potential shocks that may be captured by years fixed effects might arise. It may also happen that the labour shortage response of the different groups may be different over time. Some explanatory analyses carried out separately have suggested

that the period 2016 to 2019 could be quite specific. Then, to take this period specifically into account, we built a recent period variable.

Based on these variables, we built 6 models likely to describe the relationship between our 6*2 dependent variables, i.e. the employment growth of a given group of workers, and labour shortage intensity. The first two models, M1 vs M2, are dedicated to checking whether a threshold jump may matter or not. M3 vs M4 re-examine such a question by specifically focusing on the recent period, while M5 vs M6 extend further this exam, by making the distinction between time-varying continuous response vs time-varying response with regime jump.

All the following models (model 1 to model 6) control for workers' group age and overall employment growth during the horizon examined ($t/t+1$ or $t+1/t+2$). The latter variable is dedicated to controlling for the usual mechanism behind the growth of a worker group. Indeed, a given group of workers may simply increase because it operates within an ISCO category where the overall employment is growing. The models also include year fixed effects to control for potential timing shocks, and ISCO 1-digit fixed effects to control for skilled-level group opportunities. Three potential levels of outliers regarding labour shortage are considered: 5%, 7.5% and 10% (i.e. 2.35, 2.0, 1.8). In most cases, the 5% level is retained. The dependent variables were also winsorized at the 90% level for the CB workers groups, and at the 95% level for the natives and other foreign groups. Only observations more recent than 2012 are considered. The last year available is 2019. All the standard errors are clustered at the ISCO 3-digit level. All these models were successively applied to the 6 groups of workers for both $t+1$ and $t+2$.

Additional control variables, such as working condition factors, women's share, part-time share, and wages, are not considered at this step dedicated to building parsimonious models. Indeed, in most of the case, these variables include missing observations, introducing additional complexity in the models. These other variables are then treated, one by one, in extended models, taking into account whether sample composition vs the variables themselves may play a role in the model adjustments.

The selection of the most relevant model for a given group of workers in $t+1$ and then $t+2$ is carried out by applying the following sequence:

- Is there evidence for a smooth shortage response? If yes, Model 1 can be retained.
- Is a discrete threshold jump also needed? If yes, Model 2 should replace Model 1.
- Is the response particularly concentrated in 2016-2019? If yes, Model 3 or Model 4 should be considered.

- Does the curve formally change over time? If yes, Model 5 is relevant.
- Do the jump and curve jointly change over time? If yes, Model 6 is relevant.

The precise formal tests carried out are detailed in Table 2.

Table 2. Exact formal tests carried out for the M1-M6 models

Model	Main structure	Formal Wald/F and WCB tests	df
M1	Full-period smooth quadratic	S_{above} and S_{above}^2 jointly	2
M2	Full-period jump + quadratic	Jump + S_{above} + S_{above}^2 jointly	3
M2		Shape only: S_{above} + S_{above}^2	2
M2		Jump only	1
M3	Recent smooth quadratic	S_{above} + S_{above}^2 on the 2016-19 sample	2
M4	Recent jump + quadratic	Jump + S_{above} + S_{above}^2 on 2016-19 sample	3
M4		Shape only	2
M4		Jump only	1
M5	Smooth curve changes after 2015	$recent \times S_{above}$ + $recent \times S_{above}^2$	2
M6	Jump + curve change over time	$recent \times jump$ + $recent \times S_{above}$ + $recent \times S_{above}^2$	3
M6		Baseline jump + all 3 recent interactions	4

Notes: Wald/F refers to conventional cluster-robust test. WCB refers to wild cluster bootstrap test. Df refers to number degrees of freedom, corresponding to the number of parameters used.

4.3 Models selected by workers groups and time

The application of our model detection, described just above, leads to selecting only three relevant models for our six workers groups in t+1, and three in t+2. In other words, not all workers groups respond strongly enough in both periods to labour shortage to suggest a relevant relationship between both variables. In most of the case the groups appear to respond to labour shortage intensity, either quickly, i.e. in t+1 as for French CB workers, the natives and European non-EU15, or with some delay, i.e. in t+2, as for Belgian and German CB workers and still the European non-EU15. In addition, the shape of the response can also differ, with a U-shaped or an inverted U-shaped (see Table 3 for the tests leading to selecting the relevant model, Table 4 for additional details and Appendix C for the graphs of the fitted relevant models).

Table 3. Final 12-cell model-selection table

Group	Horizon	Selected model	Z	Exact principal test(s)	Wald/F (p)	WCB (p)
FR CB	t+1	M1	2.35	2-df S_{above} , S_{above}^2	.1477	.1443
FR CB	t+2	M1	2.35	2-df S_{above} , S_{above}^2	.2215	.2609
DE CB	t+1	M1	2.35	2-df S_{above} , S_{above}^2	.9872	.9903
DE CB	t+2	M3	2.35	Recent-period 2-df S_{above} , S_{above}^2	.0265	.0520
BE CB	t+1	M1	2.35	2-df S_{above} , S_{above}^2	.7393	.7520
BE CB	t+2	M2	2.35	3-df full / 2-df shape / 1-df jump	.0643 / .0278 / .0288	.1055 / .0529 / .0340
NAT	t+1	M1	2.35	2-df S_{above} , S_{above}^2	.0256	.0478
NAT	t+2	M1	2.35	2-df S_{above} , S_{above}^2	.2108	.2360
EU15	t+1	M1	2.00	2-df S_{above} , S_{above}^2	.1923	.2065
EU15	t+2	M2	2.35	3-df full / 2-df shape / jump inspected	.1808 / .0950	.2300 / .1221
non-EU15	t+1	M1	2.35	2-df S_{above} , S_{above}^2	.0845	.1257
non-EU15	t+2	M6	2.35	3-df temporal / 4-df expansion	.0195 / .0207	.0700 / .0608

Source: EU-LFS datasets 2013 to 2019. The sample is restricted to Luxembourg. Aggregation at ISCO 3-digit level were carried out. Samples from the neighbouring regions i.e. Lorraine (FR), Wallonia (BE) and Rhineland-Palatinate (DE) were used to compute the share of CB workers and its variation over time.

Notes: Wald/F refers to conventional cluster-robust test. WCB refers to wild cluster bootstrap test. Z corresponds to the outliers deletion. Three potential levels of outliers regarding labour shortage are considered 5%, 7.5% and 10% (i.e. 2.35, 2.0, 1.8).

Table 4. Additional characteristics of the models

Group	Horizon	Model	Z	Threshold jump at 0.99	S _{above}	S _{above} ²	Shape above threshold	Turning point (raw shortage)	Zero crossing(s) above 0.99
FR CB	t+1	M1	2.35	None	0.346	-0.384	Inv. -U	1.440	1.889
FR CB	t+2	M1	2.35	None	-0.141	0.194	U-shaped	1.352	1.715
DE CB	t+1	M1	2.35	None	-0.031	0.023	Weak U-shaped	1.655	2.319
DE CB	t+2	M3	2.35	None	0.565	-0.534	Inv.-U	1.519	2.048
BE CB	t+1	M1	2.35	None	0.079	-0.017	Positive, flattening over support	3.370 >Z	5.749 >Z
BE CB	t+2	M2	2.35	0.186	-0.944	0.717	U-shaped after positive jump	1.648	1.232; 2.063
NAT	t+1	M1	2.35	None	-0.153	0.275	U-shaped	1.267	1.544
NAT	t+2	M1	2.35	None	-0.066	0.001	Essentially declining over support	28.365 >Z	55.740 >Z
EU15	t+1	M1	2	None	0.334	-0.546	Inv. -U	1.296	1.602
EU15	t+2	M2	2.35	-0.083	0.319	-0.174	Inv. -U after negative jump	1.908	1.306; 2.510 >Z
non-EU15	t+1	M1	2.35	None	0.443	-0.469	Inv. -U	1.462	1.935
non-EU15	t+2	M6	2.35	See Table below					

Source: EU-LFS datasets 2013 to 2019. The sample is restricted to Luxembourg. Aggregation at ISCO 3-digit level were carried out. Samples from the neighbouring regions i.e. Lorraine (FR), Wallonia (BE) and Rhineland-Palatinate (DE) were used to compute the share of CB workers and its variation over time.

Notes: Wald/F refers to conventional cluster-robust test. WCB refers to wild cluster bootstrap test. Z corresponds to the outliers deletion. Three potential levels of outliers regarding labour shortage are considered 5%, 7.5% and 10% (i.e. 2.35, 2.0, 1.8). The turning point highlights the minimum of maximum of the labour shortage response. This figure can be higher than the outliers used (Z). “Zero crossing(s) above 0.99” identifies the level(s) at which the estimated shortage-related response becomes equal to zero. Threshold jump at 0.99 highlights whether discrete change apply when the labour-shortage indicator crosses the 0.99 threshold, and the size and sign of this shift.

Extension for non-EU15 t+2 (M6): period-specific adjustments

Period	Threshold jump at 0.99	S_above	S_above ²	Shape	Turning point	Zero crossing(s)
2013/2015	-0.455	3.075	-2.758	Strong inv. -U	1.547	1.165; 1.929
2016/2019	0.112	0.037	-0.072	flattened inverted-U	1.25	2.527>Z

(See appendix C for the graphs of the fitted models).

To validate these results, different tests were applied to the coefficients of the models in t+1 and t+2. The first one was an overall test regarding the t+1 and then t+2 beta coefficients, then checking whether a relationship can be found between labour shortage intensity and the subsequent growth of the different groups of workers. The result is significant for both t+1 [$\chi^2(10) = 16.43$, $p=0.08$] and t+2 [$\chi^2(13) = 39.52$, $p=0.0002$], but the effect is clearly stronger in t+2. For t+1, it is only significant at the 10% level. To fine-tune these results, pairwise combinations for t+1 and t+2 were considered. For t+1, only three cases are significant: natives – French CB, natives - EU15 and natives – European non-EU15. Although the model is consistent in t+1 for the French CB workers and European non-EU15 workers, we don't find any additional significant combinations for them, including between them. The latter non-significant result could be explained by the relatively similar adjustments of the two groups of workers, including inverted U-shaped adjustments. On the opposite, part of the three significant results involving natives may be due to the rather specific shape of their adjustments, with a U-shape not present for the other cases in t+1. The similar tests for t+2 highlight more important gaps between the groups of workers. Part of these greater gaps seem related to the more diverse models used for t+2 adjustments, leading to more heterogeneous kinds of adjustments. Results highlight as well a U-shaped response to labour shortage intensity for Belgian CB workers, with rather high response from them for both low and high labour shortage, while response from German CB workers is focused at moderated intensity level. Such a specific pattern by labour shortage intensity leads us to extend our test by including in it, response to low, moderate, or high labour shortage. This test is applied to all the groups, and then to pairwise combinations, for both t+1 and t+2. The results confirm stronger gaps in t+2 than in t+1. However, part of the difference may still be due to the heterogeneity of models applied in t+2, while a unique model is selected in t+1, i.e. model 1.

4.4 Does extended model matter: does additional variable may play a role including variable related to the cross-border regions?

All the models previously examined were based on parsimonious models not including all the variables available. The strategy was not to reduce the size of the model, which was already quite small, and not to set up the model based on specific sample compositions. However, such a strategy may also lead to excluding variables or sample compositions that could be relevant in the response to labour shortage. It remains then to check whether the inclusion of additional variables may be relevant. In our tests, we make the distinction between sample composition and the effect of the added variables. We examine more practically whether any additional variable would change the strength of the previous tests carried out and the shape of the labour shortage response by making the distinction between the reduced sample composition and the specific effect of the variable.

As expected, the additional variables do not change the previously inconsistent models much. The main exception is for the French CB workers in t+2 for which using ISCO 2-digit fixed effects leads to relevant results. The additional variables indeed play a more relevant role in the already consistent models, as with French CB workers in t+1 in which the addition of the share of women or the working condition factors strengthens the results through both composition effects and variable effects. Working condition factors have the same double effect for natives in t+1. However, adding some variables can also weaken the previously relevant results. Indeed, adding any of the potential missing variables for EU15 workers in t+1, including age, that were in the selected model, weakens the labour shortage effect through both sample composition and variable effect. The model is only consistent when it remains even more parsimonious than in the selected model. For Europeans non-EU15 in t+2, the addition of two variables weakens the effect, i.e. the part-time share and the women share. Finally, for Belgian CB workers still in t+2, only the addition of one type of variable weakens the model: the working condition factors.

To complete this exam, we introduce a new variable available for the three groups of CB workers, i.e. relative specialisation corresponding to the log of the following quotient at ISCO 3-digit level: share of a given group by the share of the two other groups. While such a variable could affect the response to labour shortage, affecting then the growth of the group of workers indirectly in t+1 or t+2, it could also have a more direct effect on the latter. As such, it could be a competing mechanism or an alternative mechanism to labour shortage regarding the group of workers' employment growth. To test for the direct effect, we add the variable as an additional covariate and also test for its sample composition. The results highlight that such a variable may play a direct role, but mostly when the examined model

is not consistent, i.e. for French CB workers in t+2, and for Belgian and German CB workers in t+1. The only exception is that it works as well for Belgian CB workers in t+2. But the model was a bit weak. All this may suggest that such specialisation may then play a secondary role in fostering employment growth of CB workers when CB workers are not assumed to be hired.

(See Appendix D)

Table 5. Direct association of relative specialization with CB workers responses

Group	Horizon	Relevant model	N	ISCO clusters	β coef.	Clustered SE	Wald/F (p)	WCB (p)
FR CB	t+1	M1	589	112	0.004	0.02	0.852	0.863
BE CB	t+1	M1	589	112	0.041	0.022	0.061	0.078
DE CB	t+1	M1	589	112	0.048	0.018	0.007	0.006
FR CB	t+2	M1	589	112	0.033	0.018	0.073	0.093
BE CB	t+2	M2	589	112	0.043	0.018	0.016	0.025
DE CB	t+2	M3	492	112	0.017	0.015	0.255	0.274

Source: EU-LFS datasets 2013 to 2019. The sample is restricted to Luxembourg. Aggregation at ISCO 3-digit level were carried out. Samples from the neighbouring regions i.e. Lorraine (FR), Wallonia (BE) and Rhineland-Palatinate (DE) were used to compute the share of CB workers and its variation over time.

Notes: Wald/F refers to conventional cluster-robust test. WCB refers to wild cluster bootstrap test.

5 Discussions and conclusion

Our fitted models suggest that the response to labour shortages can be quick or delayed, but that in most of the cases, groups of workers respond to it. Such a response also varies by labour shortage intensity, with, e.g. a response to low labour shortage in t+1 for French CB workers and European non-EU15, and a response still in t+1 but for high labour shortage for the natives. In t+2, when a response from Belgian and German CB workers appears, even mode diversity stands out between the relevant models. While the Belgian CB workers are more likely to be hired either when labour shortage is low or high, the German CB workers are more often hired when labour shortage is moderate. However, the latter result with German CB workers holds only for the end of our observation period, i.e. 2016-2019. Furthermore, and still in t+2, the shape of the adjustment for European non-EU15 appears different between 2013-2015 and 2016-2019.

The delay between the t+1 and t+2 adjustments and some specific adjustments, such as the U-shaped and the inverted U-shaped, could be related to different specificities regarding the worker groups, such

as the size of the labour pool, the reservation wage, the main languages used, the recruitment methods used (including through peers among CB workers), the mobility of workers, and for the CB workers alternative opportunities in the cross-border regions. Any specific hiring practices by the employers should also be considered, as well as the policy framework.

The French CB workers combine different advantages with respect to the Belgian and German CB workers, which may explain a comparatively quicker response. First France provides a much larger established pool of CB workers: in 2023, approximately 119,900 employees commuted from France, compared with 54,500 from Germany and 52,400 from Belgium (STATEC, 2024). This larger pre-existing workforce may facilitate recruitment through denser information and professional networks. Second, evidence of comparatively moderate wage demands among CB workers is consistent with lower reservation wages (Brosius et al., 2014). However, a more recent piece of evidence is required to more firmly establish such a finding and to examine potentially lower reservation wages among French CB workers, while the EU-SILC datasets suggest that lower median wages are offered in Lorraine than in Wallonia and Rhineland-Palatinate. Third, commuters from France are likely to face relatively limited linguistic barriers because French is the most widely used language in Luxembourg's private-sector workplaces and is present across nearly all major occupational groups (Heinz & Fehlen, 2016). Finally, they have the shortest average home-to-work distance among the three CB groups: 44.7 km for workers residing in France, compared with 48.0 km for Germany and 53.9 km for Belgium (Durand et al., 2025).

As all these advantages are related to the overall Luxembourg labour market, further analyses would be required to assess whether labour shortage moderates these advantages by increasing/decreasing them. However, as the French CB workers are mostly hired in almost usual times, i.e. when labour shortage is reduced or moderated, the potential findings of the additional analyses might be limited.

Furthermore, the finding that natives respond already at $t+1$, but only when labour shortages are particularly severe, warrants further investigation. One possibility is that this response is concentrated in public-sector employment, where native-born workers are over-represented, while it is not usually the case among private sector occupations. According to the 2021 Population Census, public administration accounts for 31.1% of resident employment and 70% of its resident workers are native-born (Verheyden et al., 2024). Another possibility would be that the hiring of natives would be particularly focused in some moderate skilled occupations, while the CB workers, from at least Belgium, were found to be focused on both ends of the skill spectrum (see Albanese & Marguerit, 2022). The inclusion of ISCO 2-digit fixed effects does not materially alter the current evidence, suggesting that it

is not driven solely by broad occupational composition. However, occupational fixed effects at the two-digit level do not distinguish public and private-sector employment and may not distinguish enough occupations in which the natives would be highly vs weakly focused. Additional analyses would therefore be required to fine-tune and extend the current evidence. Finally, the native response under particularly severe shortages could reflect not only an increase in labour supply, but also demand-side or policy-driven recruitment. Such an interpretation is plausible in Luxembourg, where public employment has historically contributed materially to net job creation: the public sector has generated approximately 1,200 jobs annually between 2010 and 2012 and accounted for 16% of net employment creation in 2012 (STATEC, 2013). The apparent bimodal response of the Belgian CB workers in $t+2$, i.e. important at low and high labour shortage, requires as well further exams to determine whether it reflects distinct adjustment mechanisms operating at different levels of shortage intensity, or whether further distinctions by socio-economic profile would be required among the Belgian CB workers. It remains also to be cautious regarding the current results at high labour shortage due to the small number of observations supporting the natives and Belgian CB workers results as shown in the fitted models found in Appendix C, with the massive widening of their respective confidence intervals at the highest shortage levels.

Analysis at a finer spatial level also offers an opportunity to examine whether adjustment to labour shortages in Luxembourg is conditioned by labour-market resources in the neighbouring regions of Lorraine, Wallonia and Rhineland-Palatinate. Luxembourg operates within a strongly integrated cross-border functional labour market in which differences in employment opportunities, unemployment, wages, transport connections, language and regional economic conditions influence cross-border mobility (Pigeron-Piroth & Belkacem, 2015; ESPON, 2021).

The results indicate that the relative occupational specialisation of workers from each neighbouring region at the ISCO 3-digit level plays a secondary additional role when the corresponding worker group exhibits a weak or delayed baseline response to labour shortages—namely French CB workers at $t+2$ and Belgian and German CB workers at $t+1$. This interpretation is consistent with previous evidence that CB workers' occupational and sectoral profiles differ by country of residence and are geographically specialised in relation to the economic structure and labour demand of the destination market (Pigeron-Piroth & Belkacem, 2015).

More generally, the findings are consistent with a hierarchy of adjustment mechanisms. Factors such as the size of the established labour pool—particularly for natives and French CB workers—the availability

of workers from additional labour pools (European non-EU15), and differences in wage demands or reservation wages (for French CB workers but also for European non-EU15) may facilitate a relatively rapid response. By contrast, adjustment among smaller or less immediately available groups, or with some disadvantage, as e.g. not speaking the main languages used, may require more time. In these cases, occupational specialisation in the region of residence may partly offset the delayed aggregate response by making appropriately qualified workers more readily available for particular occupations. It remains, however, necessary to strengthen these results and to identify causal mechanisms.

Further analysis should also be dedicated to connecting Luxembourg's occupational shortages with the corresponding components of labour supply in neighbouring regions. Relevant indicators would include occupation-specific unemployment, employment creation and labour-force participation in Lorraine, Wallonia and Rhineland-Palatinate. This extension is supported by evidence that regional employment growth can affect unemployment in neighbouring areas through commuting and other spatial labour-market interactions (Niebuhr, 2003). It is also particularly relevant in the Luxembourg functional region, an area including the neighbouring regions, because unemployment and employment rates differ markedly across its component territories: unemployment has generally been higher in Lorraine and Wallonia than in Rhineland-Palatinate, implying different reserves of potentially available labour (ESPON, 2021).

Finally, age composition appears relevant in most models providing sufficiently strong evidence of a relationship between labour-shortage intensity and employment growth by worker group. By contrast, the other extensions appear relevant only in specific cases—for example, working conditions and the share of women for French CB workers at $t+1$, and the part-time share and ISCO two-digit fixed effects for French CB workers at $t+2$. Despite its apparent relevance, age composition may be explained by different phenomenon. Occupational age structure may capture replacement demand generated by retirement, age-related differences in job tasks, and differences in occupational or geographical mobility. It may also proxy for tenure, contract type, experience, or sectoral composition. Complementary qualitative and sector-specific analyses would therefore be valuable for clarifying the potential mechanisms represented by age as well as the other covariates, in order to identify any common mechanisms across them, and determining how they might inform policies intended to alleviate labour shortages. The main result remains however that the different groups of workers seem to respond to labour shortage across different dimensions of timing and intensity. This evidence is supported by a hierarchy of adjustment mechanisms on which a policy dedicated to alleviating labour

shortage could be established, for instance by reducing the disadvantages faced by the lagging and less responsive categories of workers, drawn from a sizable labour pool.

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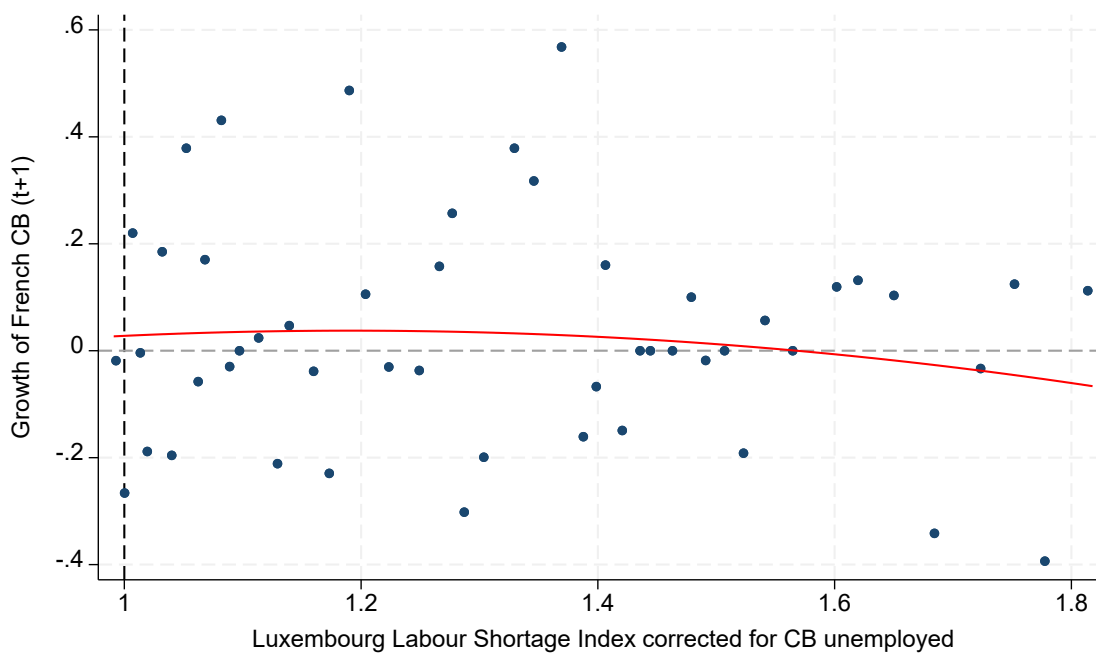
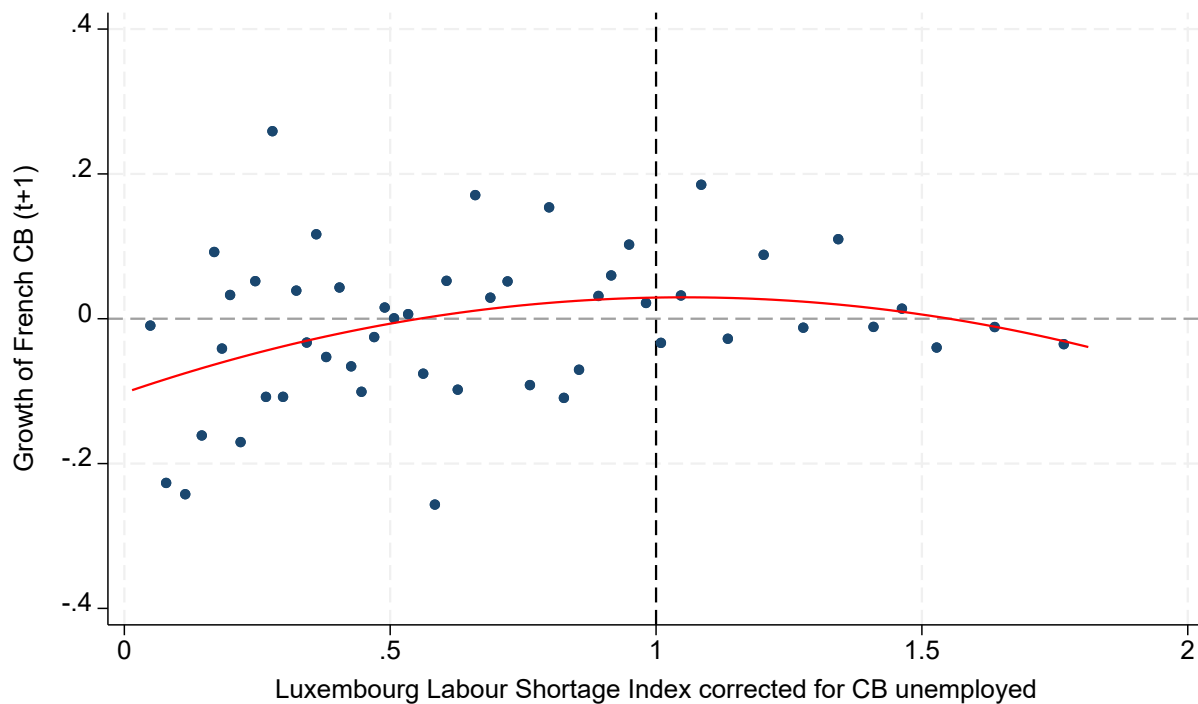
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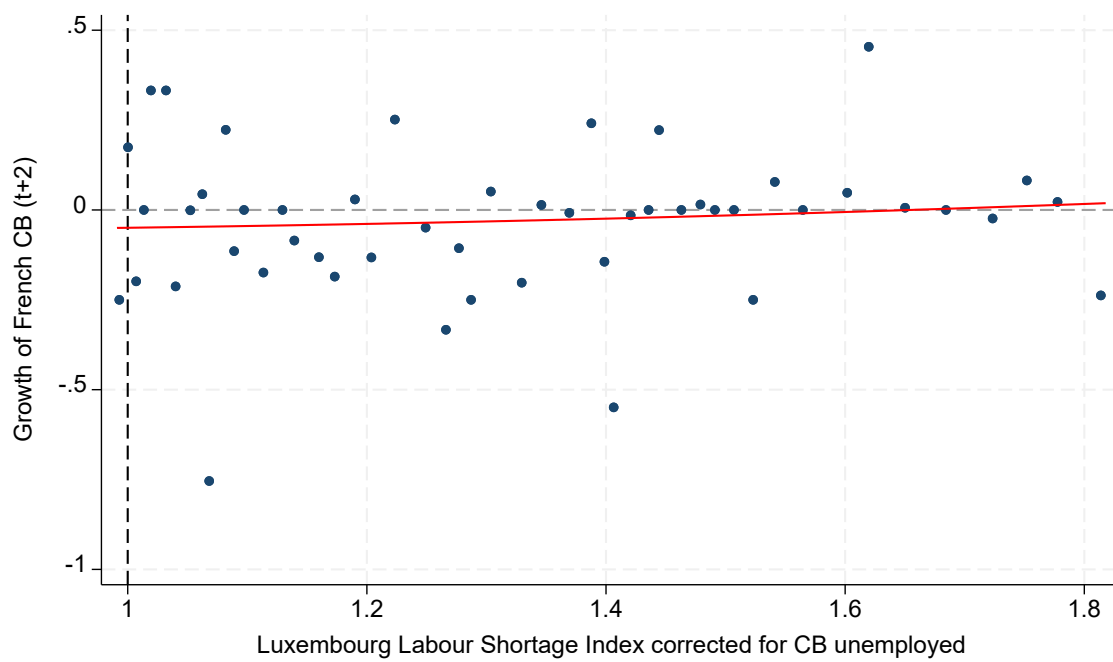
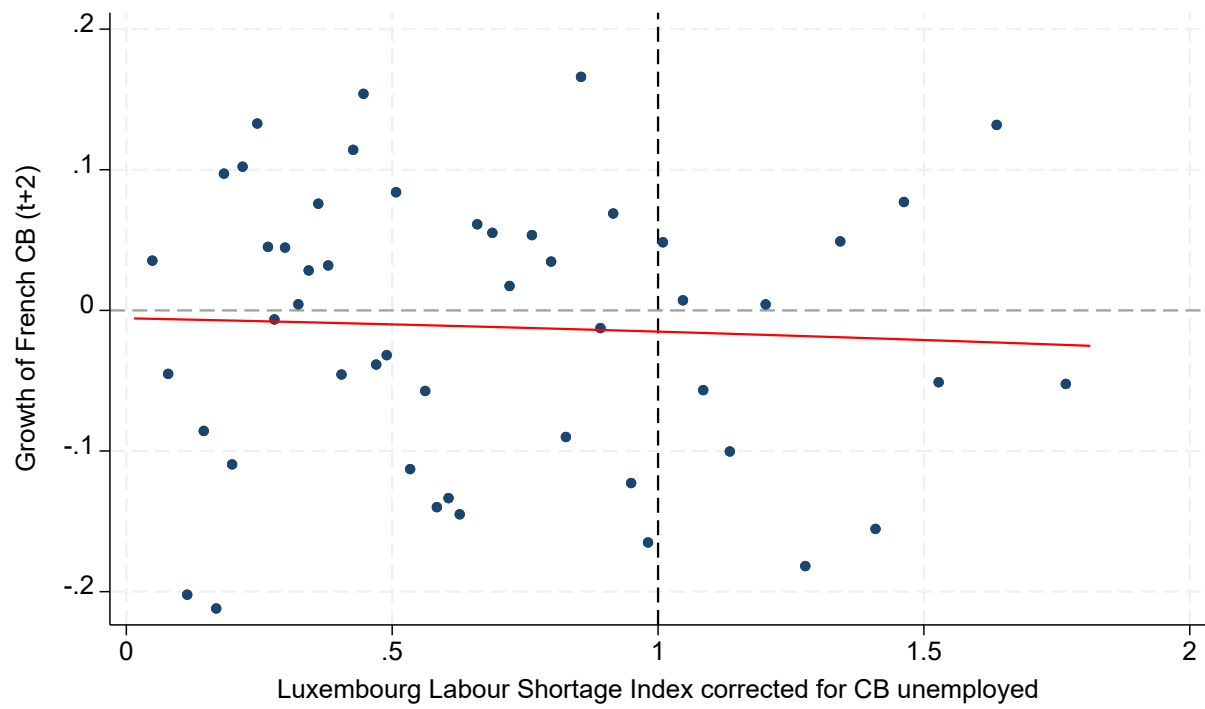
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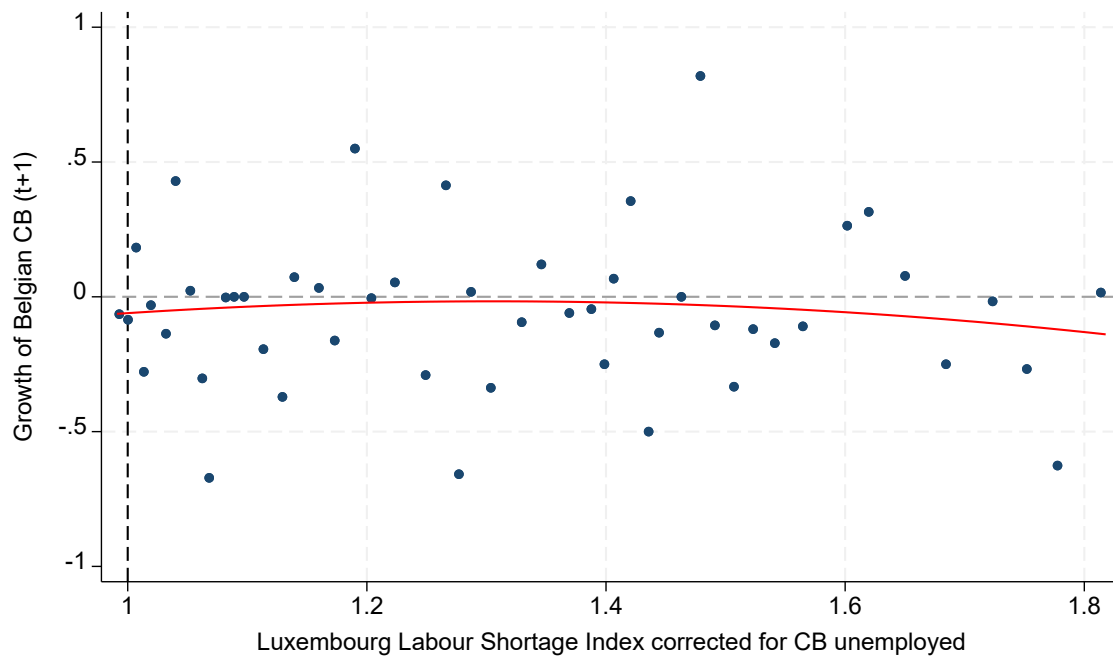
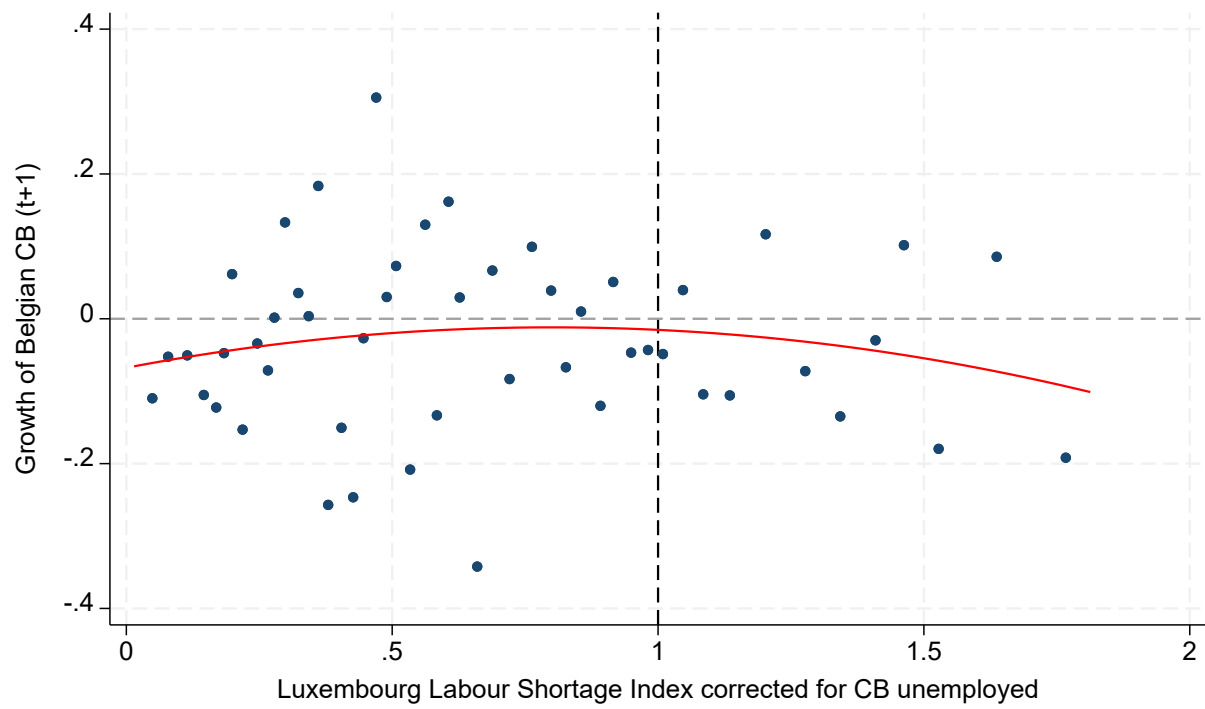
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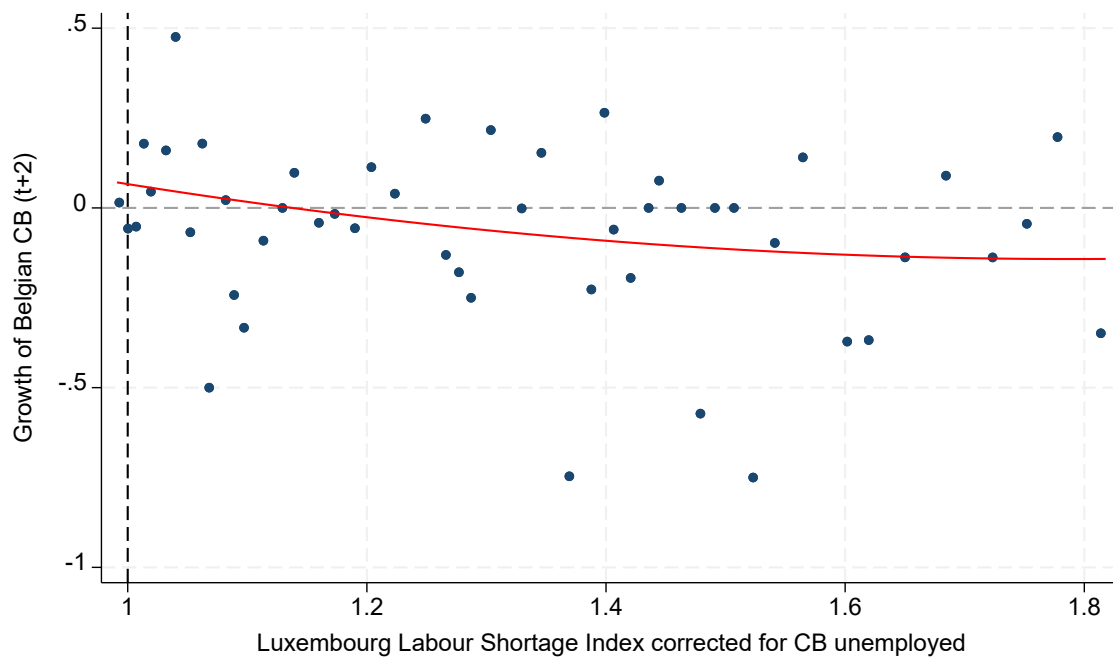
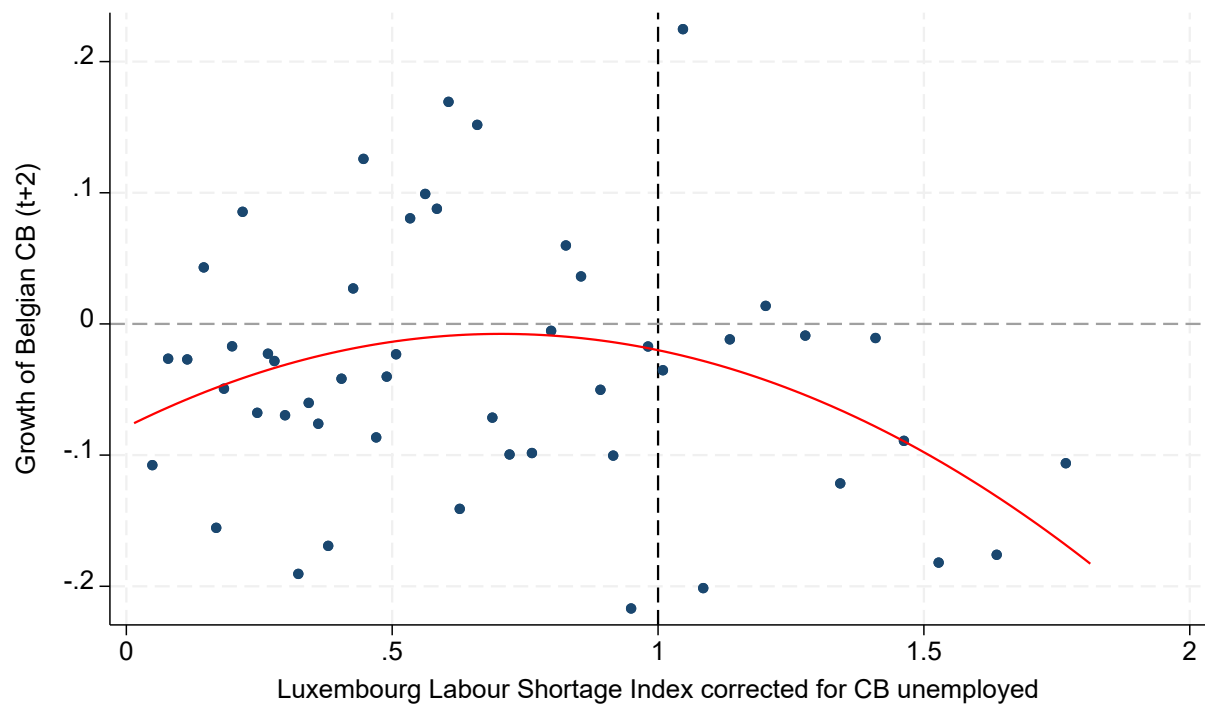
Appendix A – Relationship between labour shortage

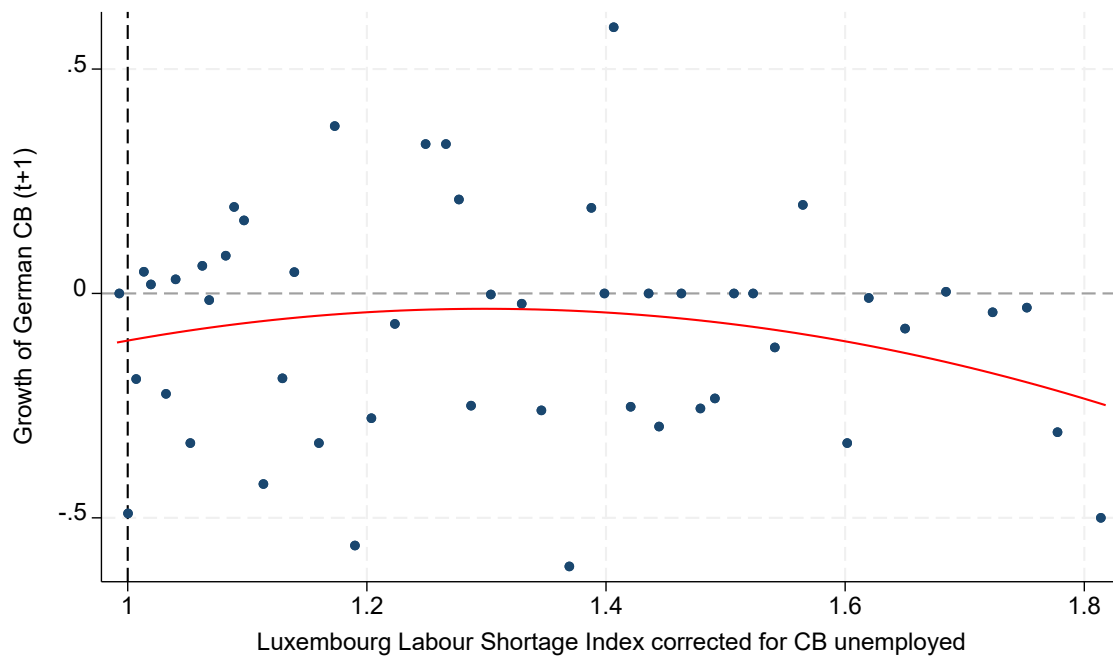
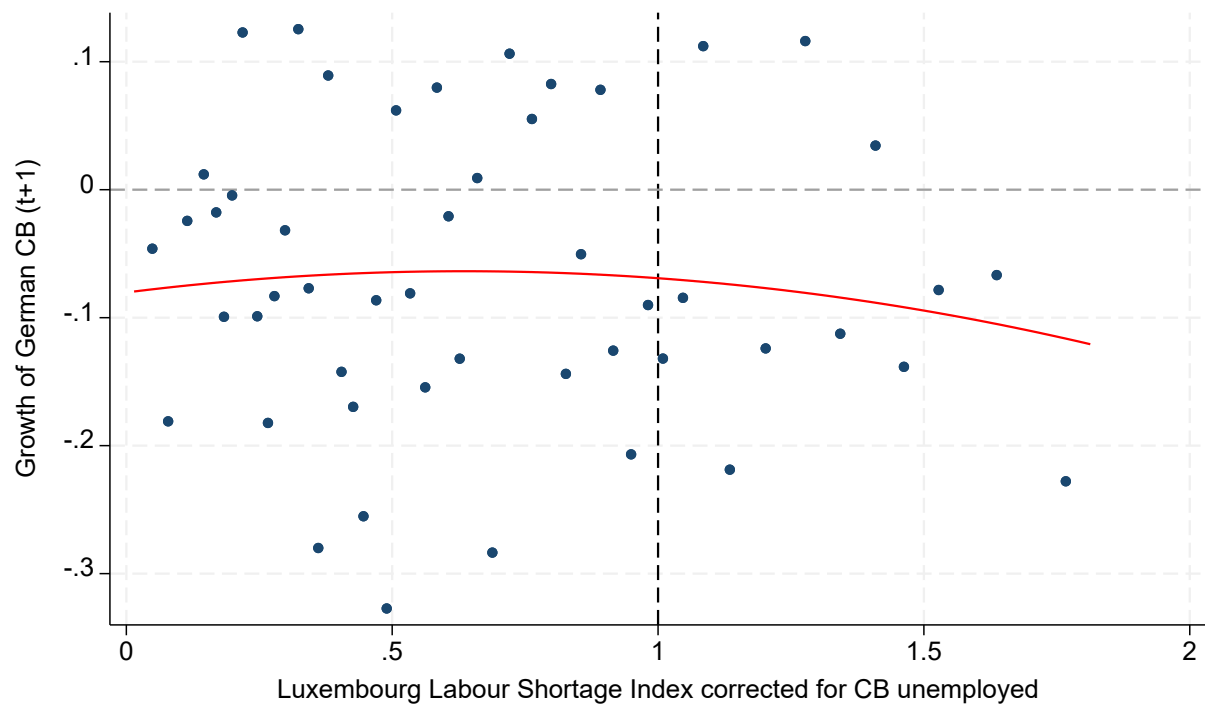
Appendix A: Relationship between labour shortage over '0 to max' and '1 to max' and employment growth of a given group of workers in t+1 or t+2

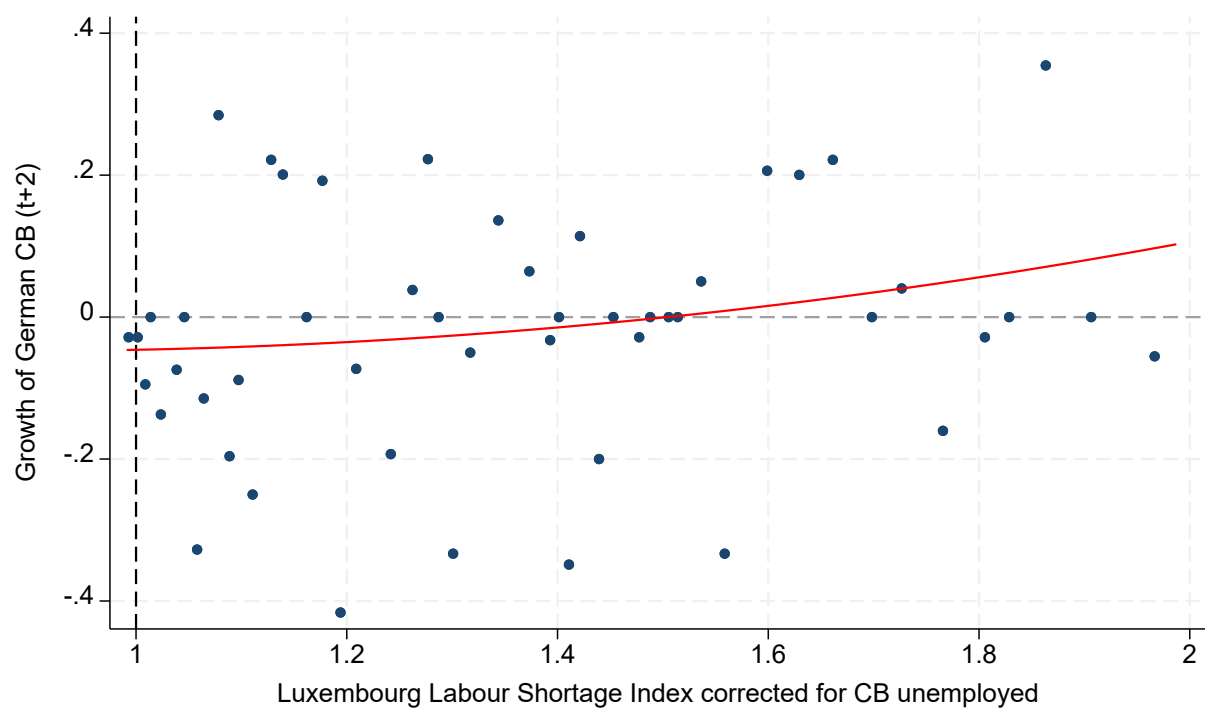
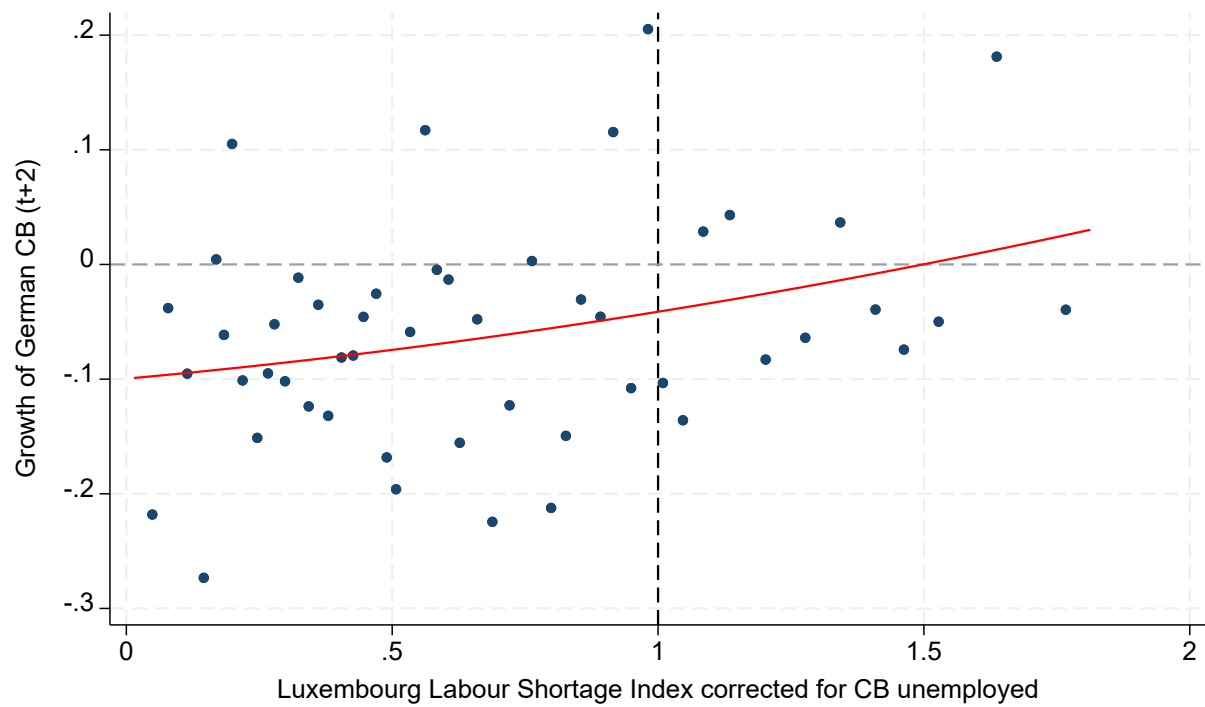


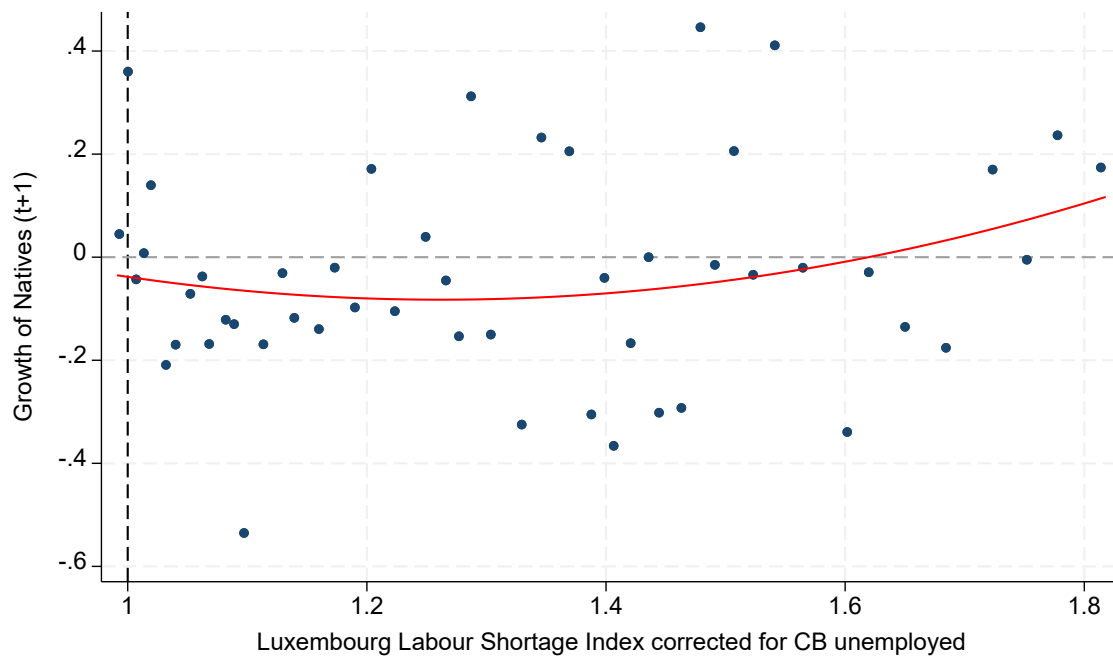
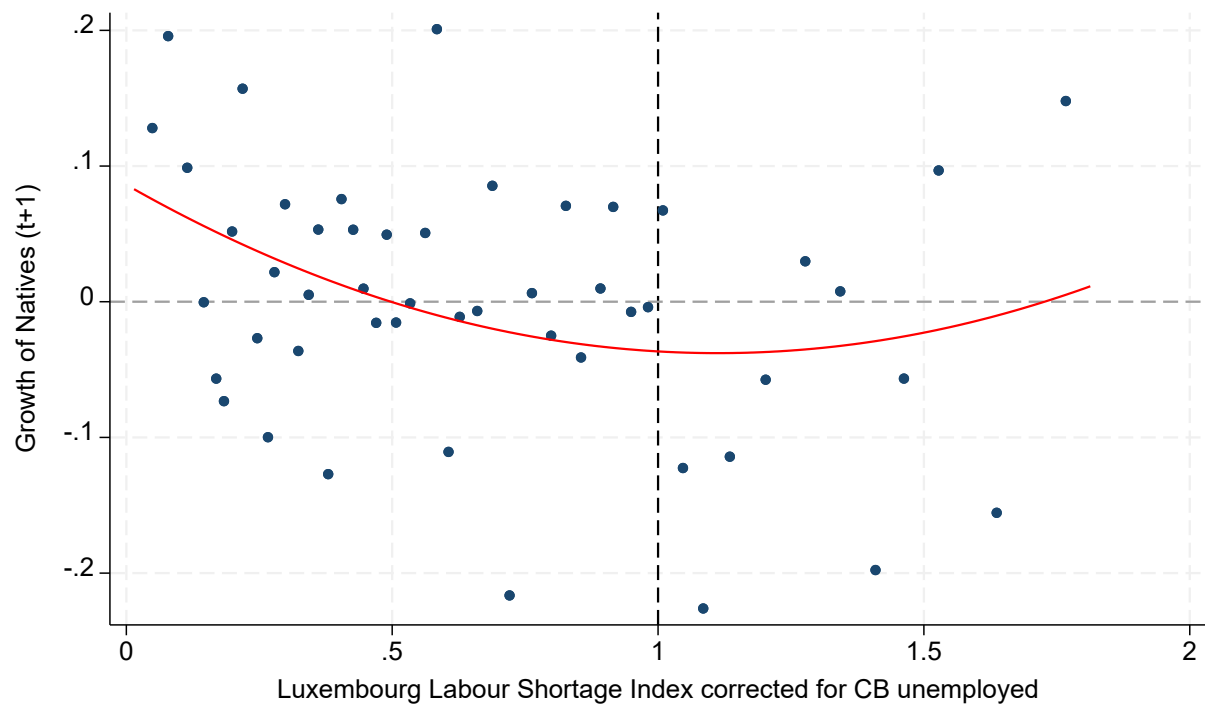


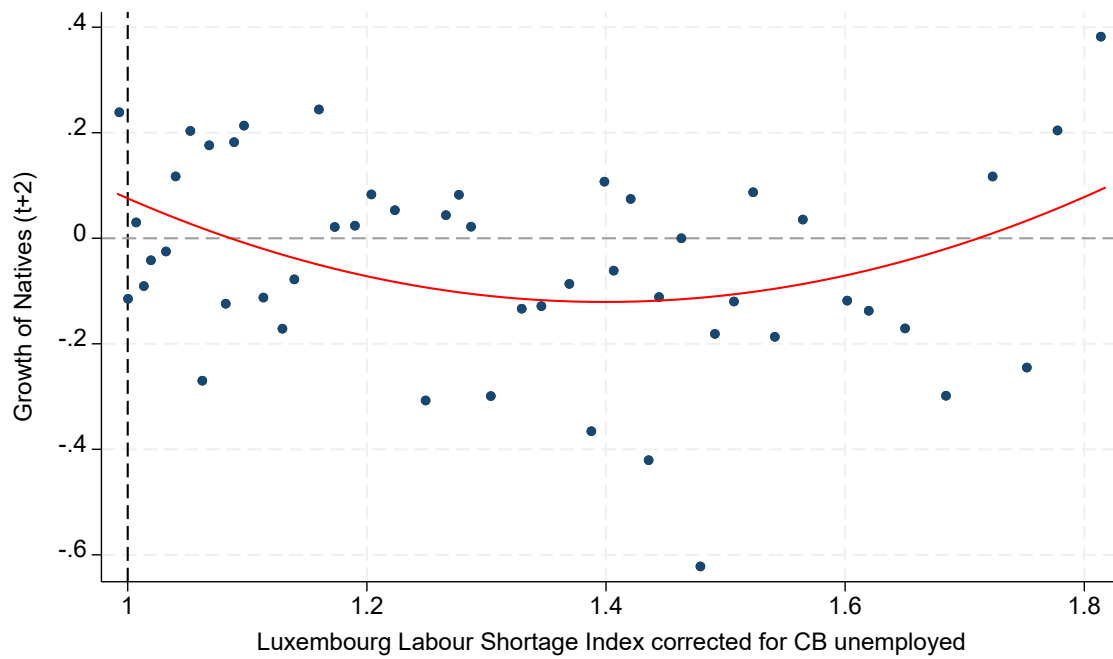
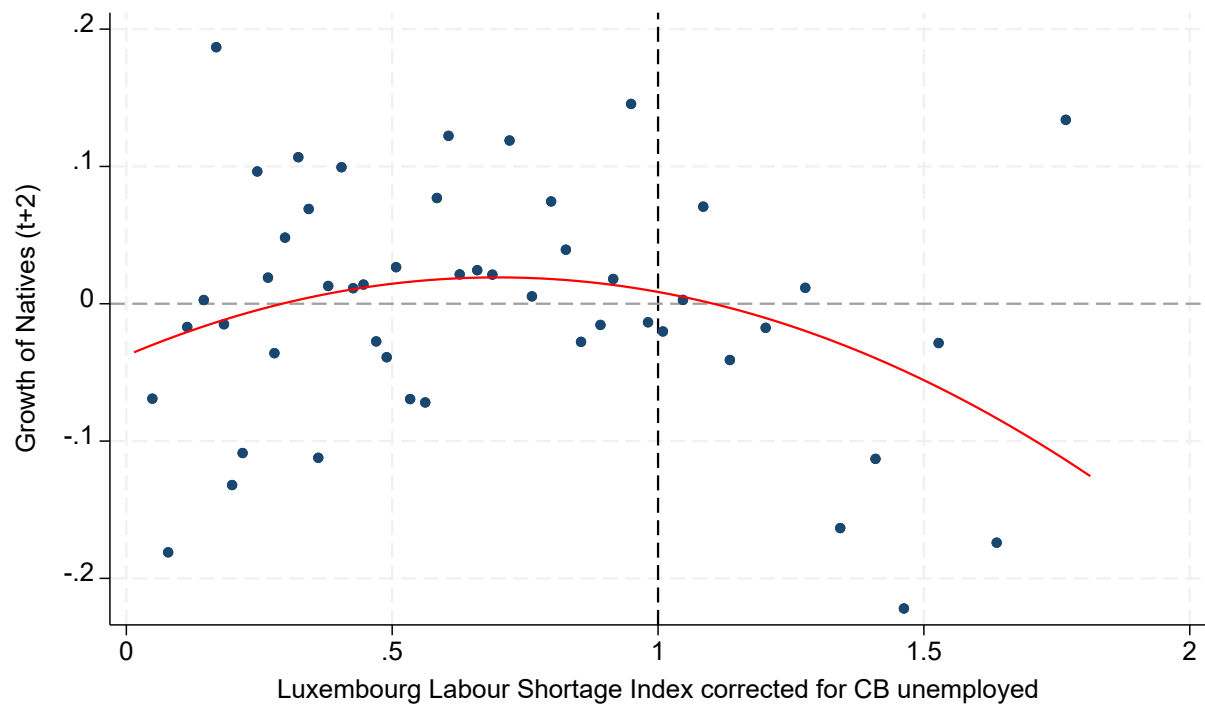


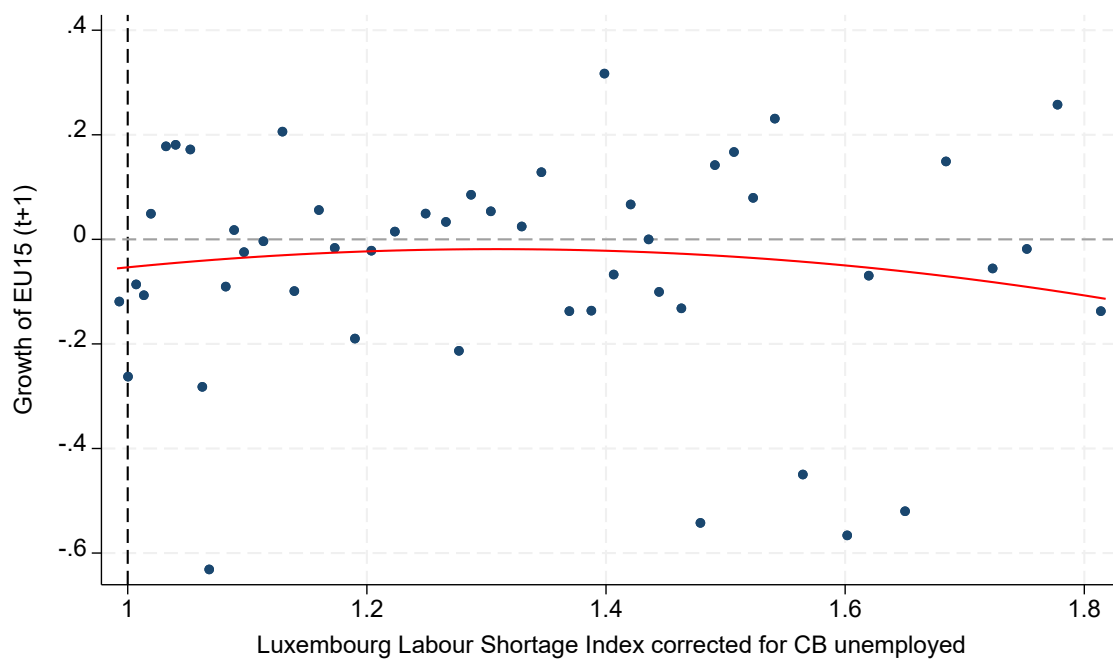
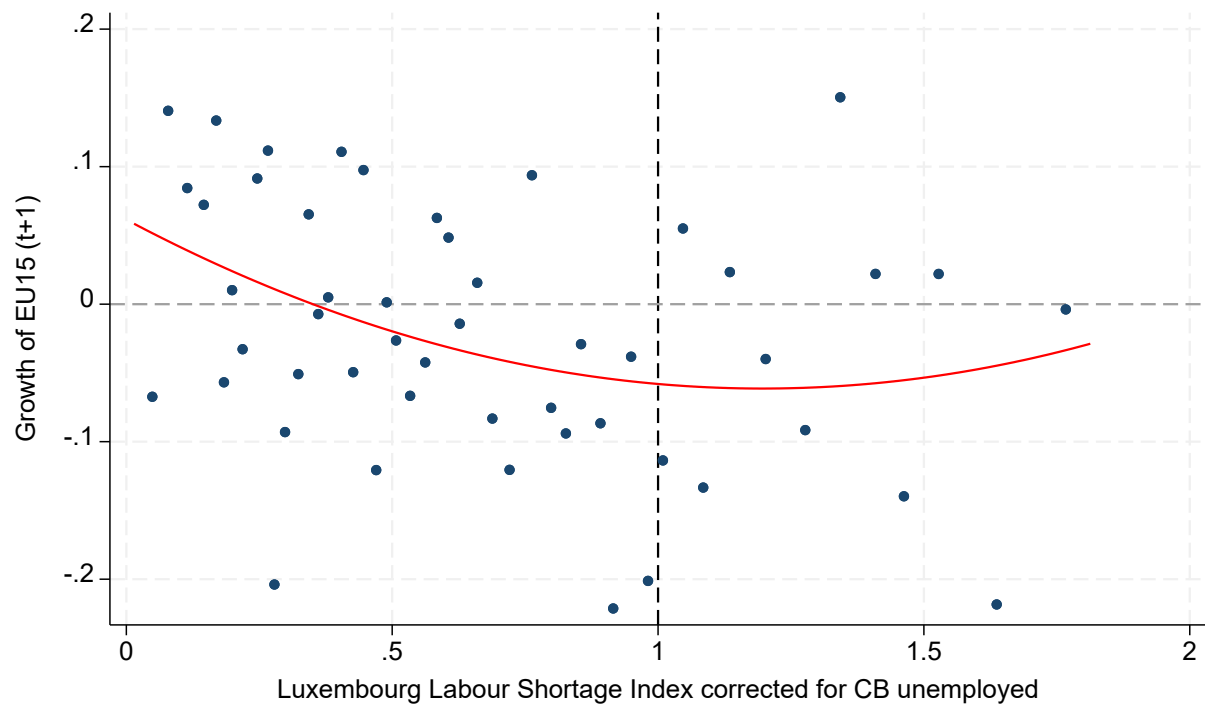


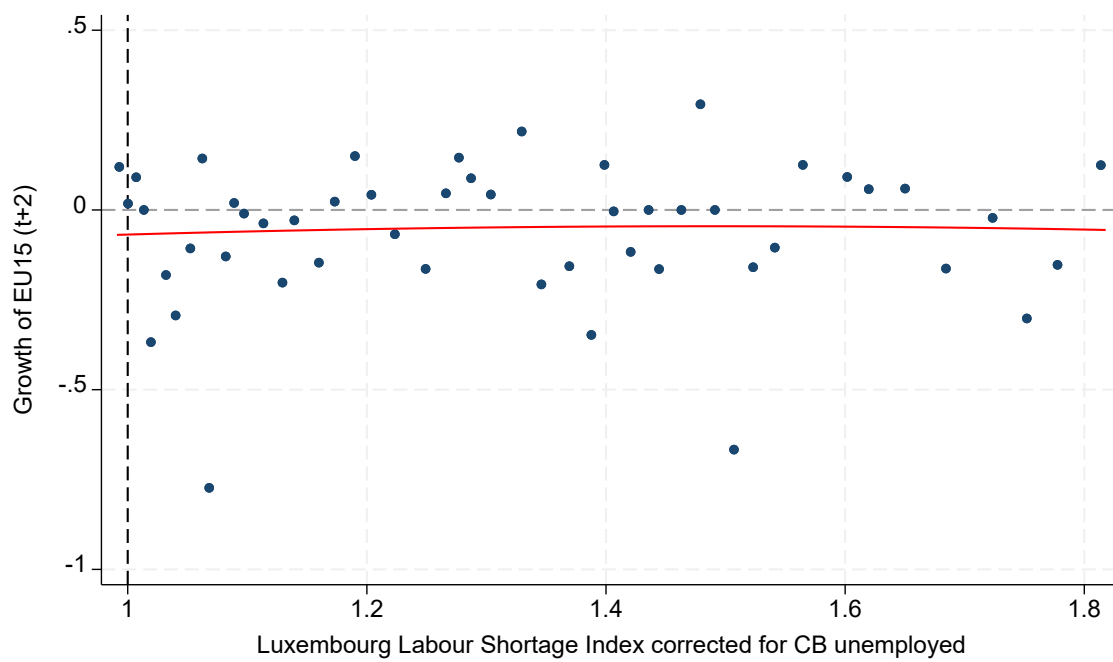
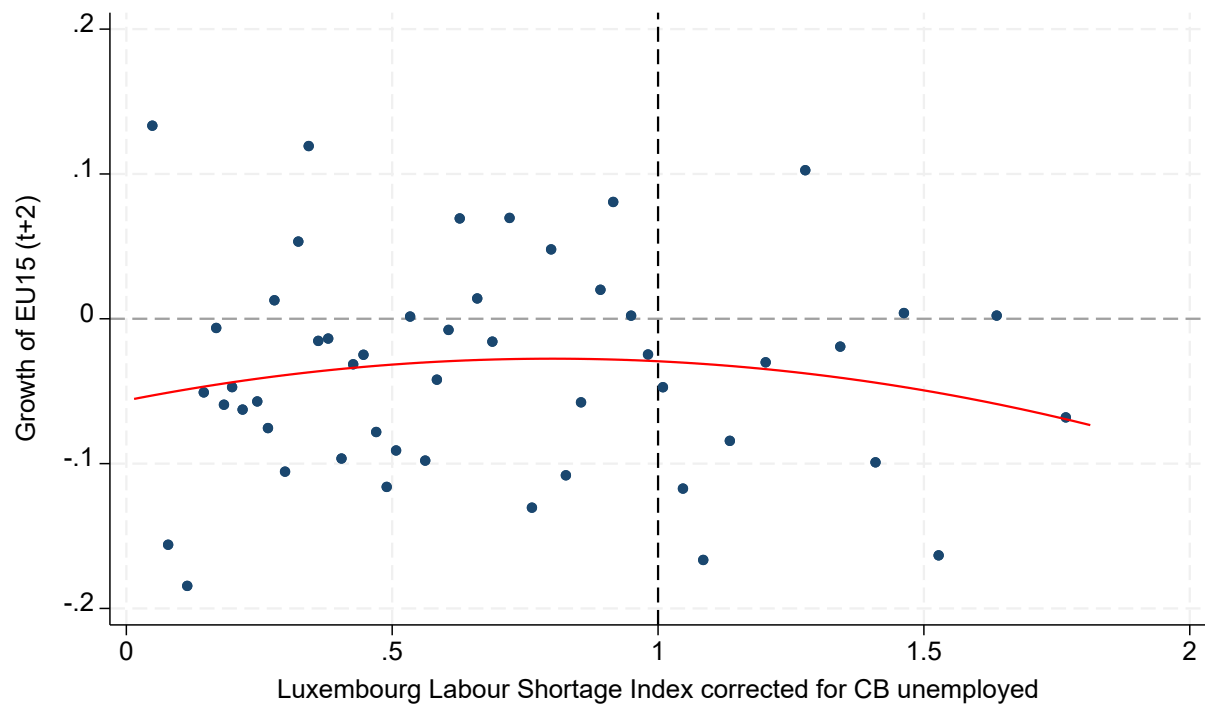


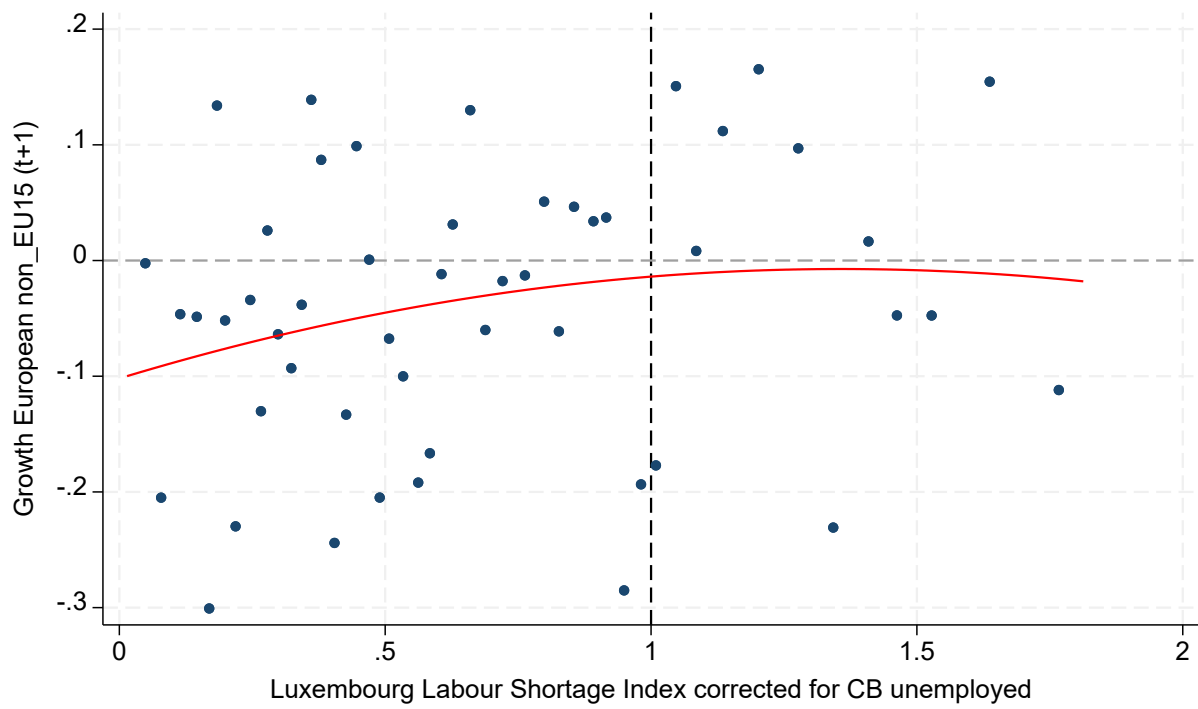


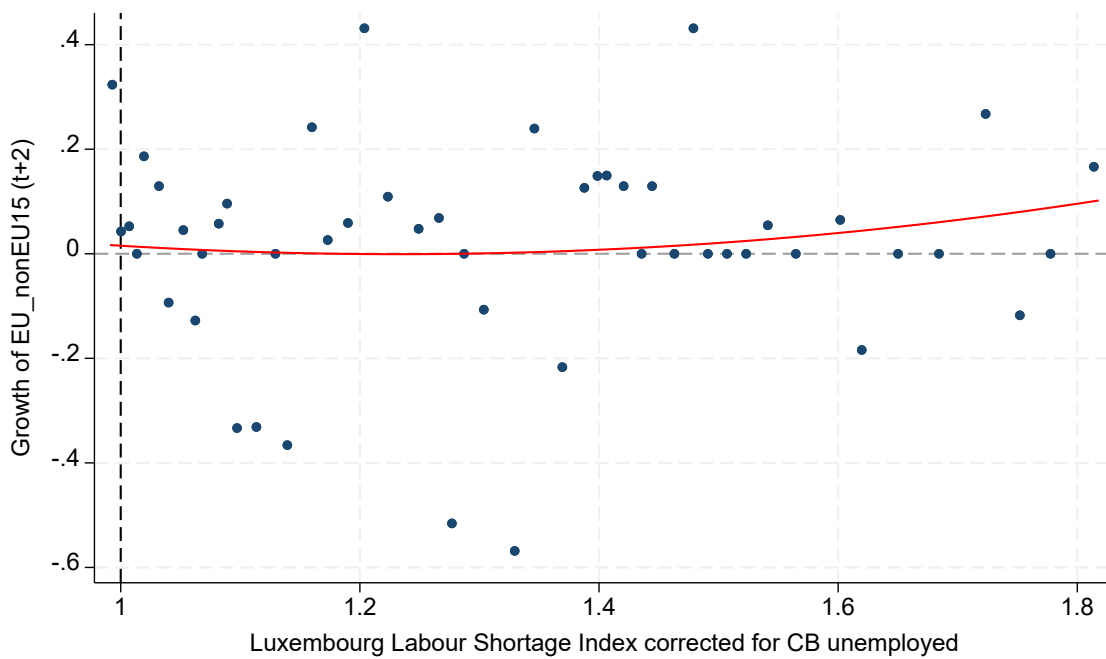
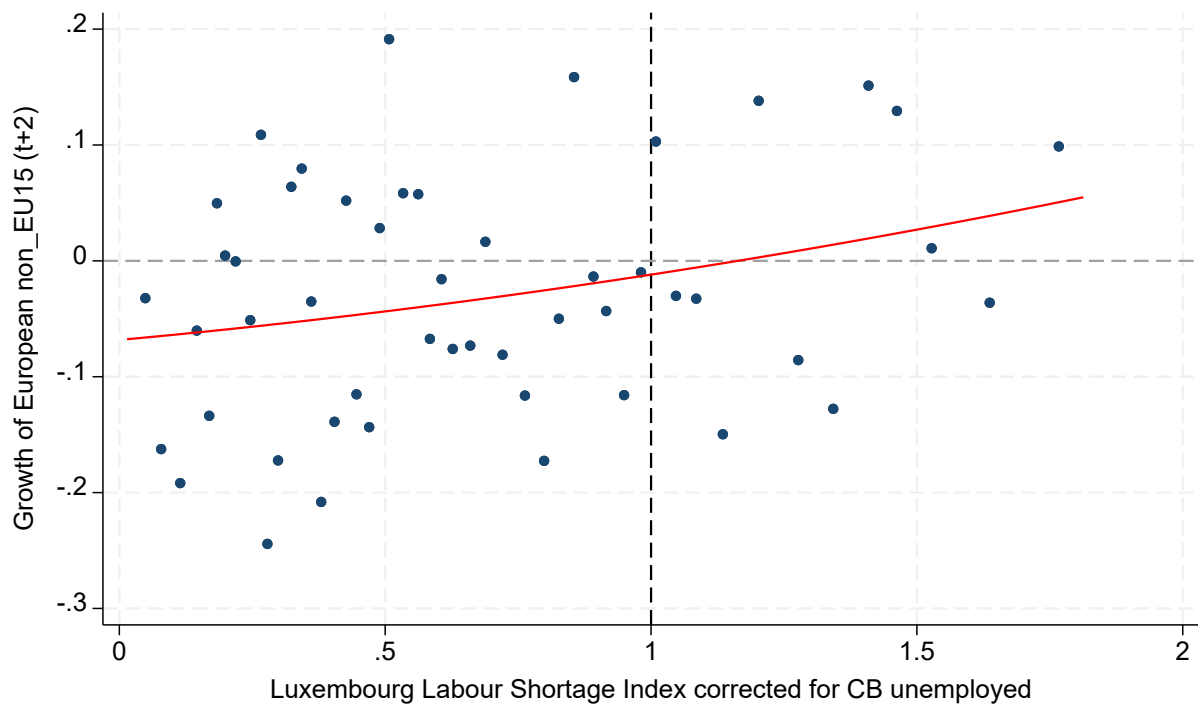






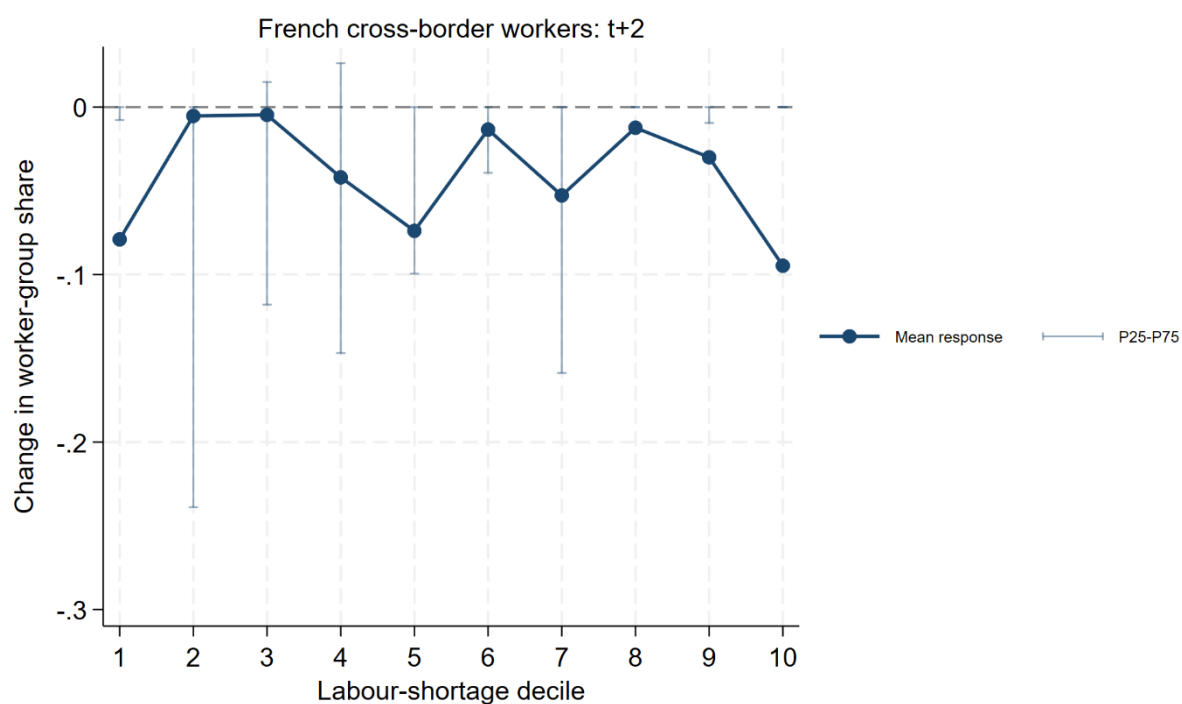
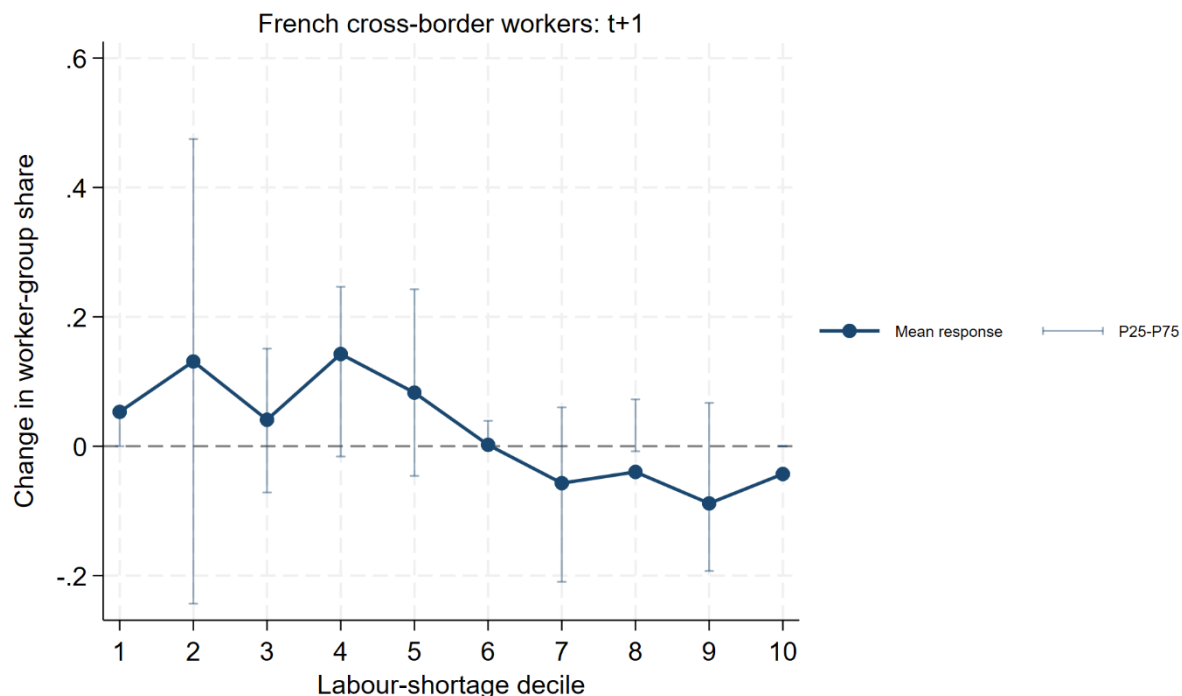


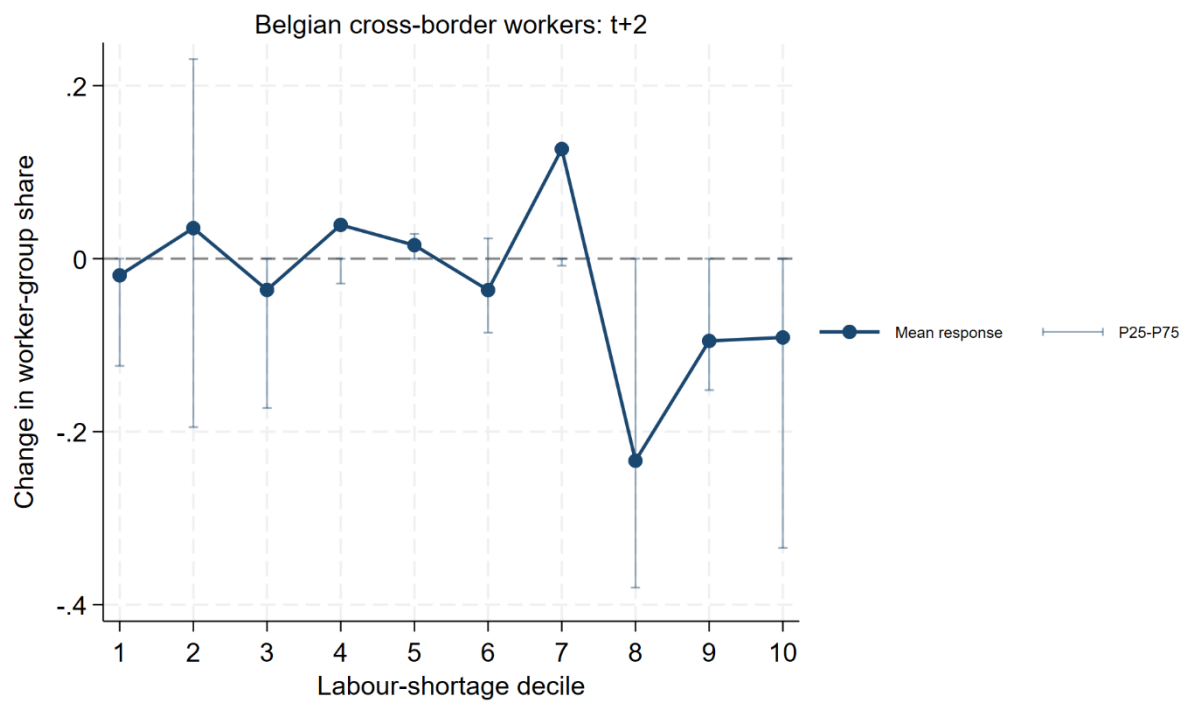
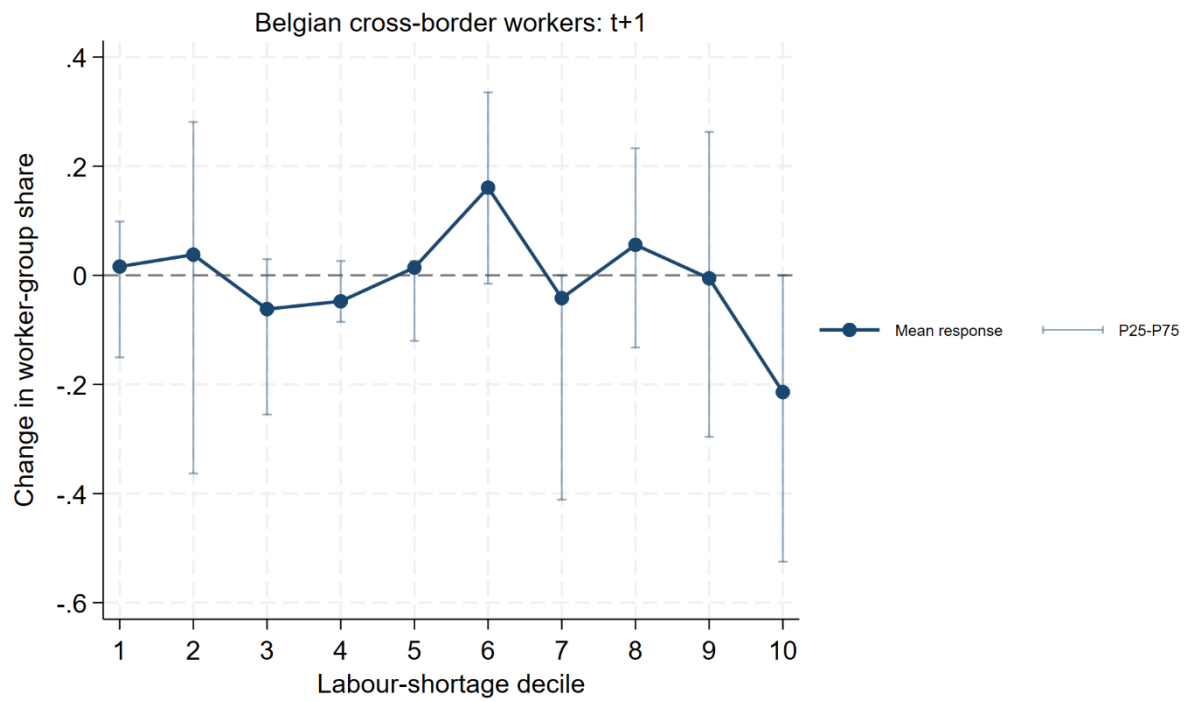


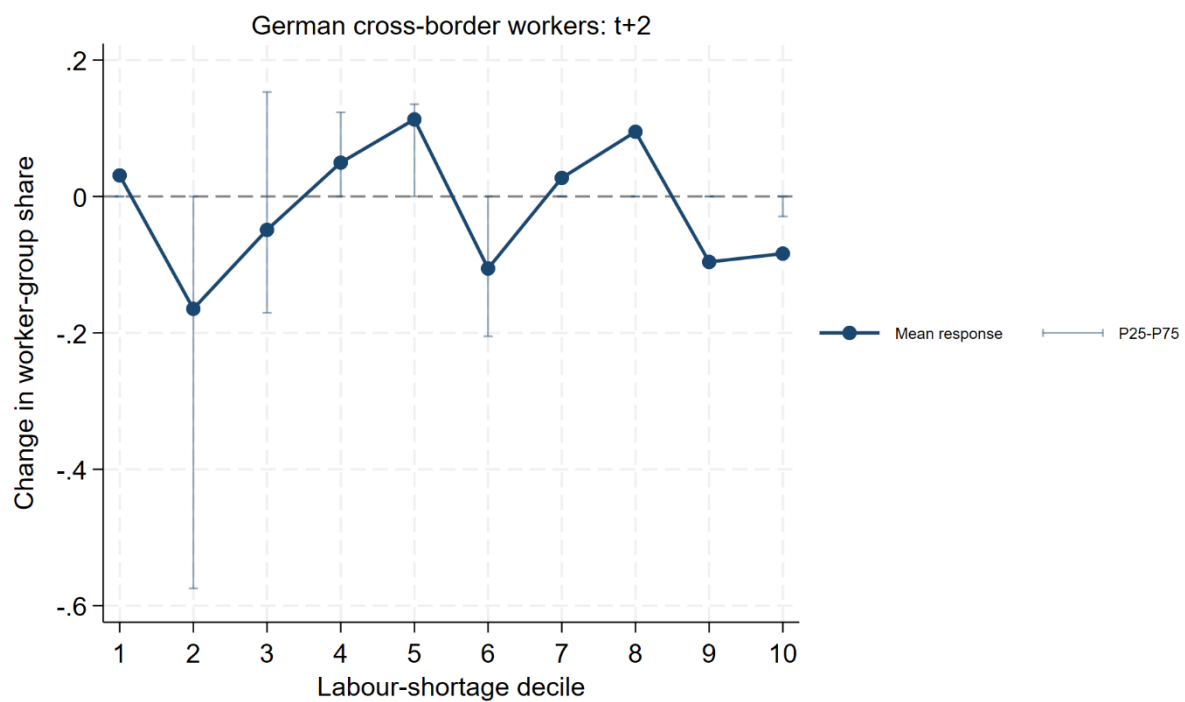
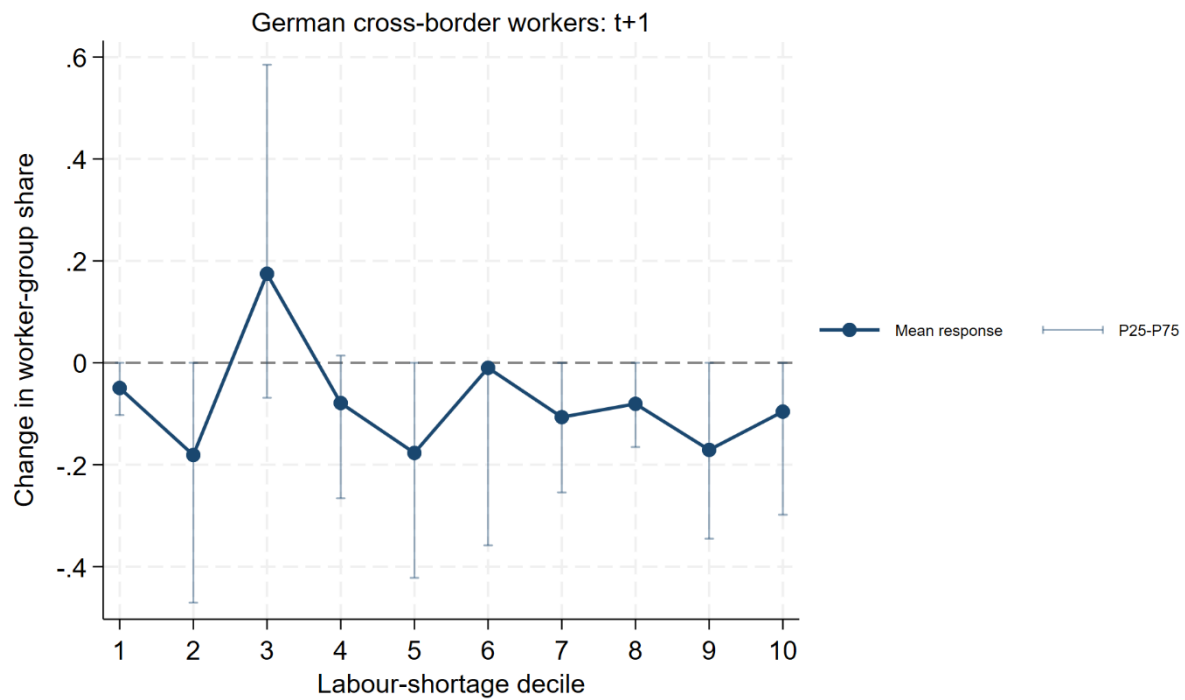


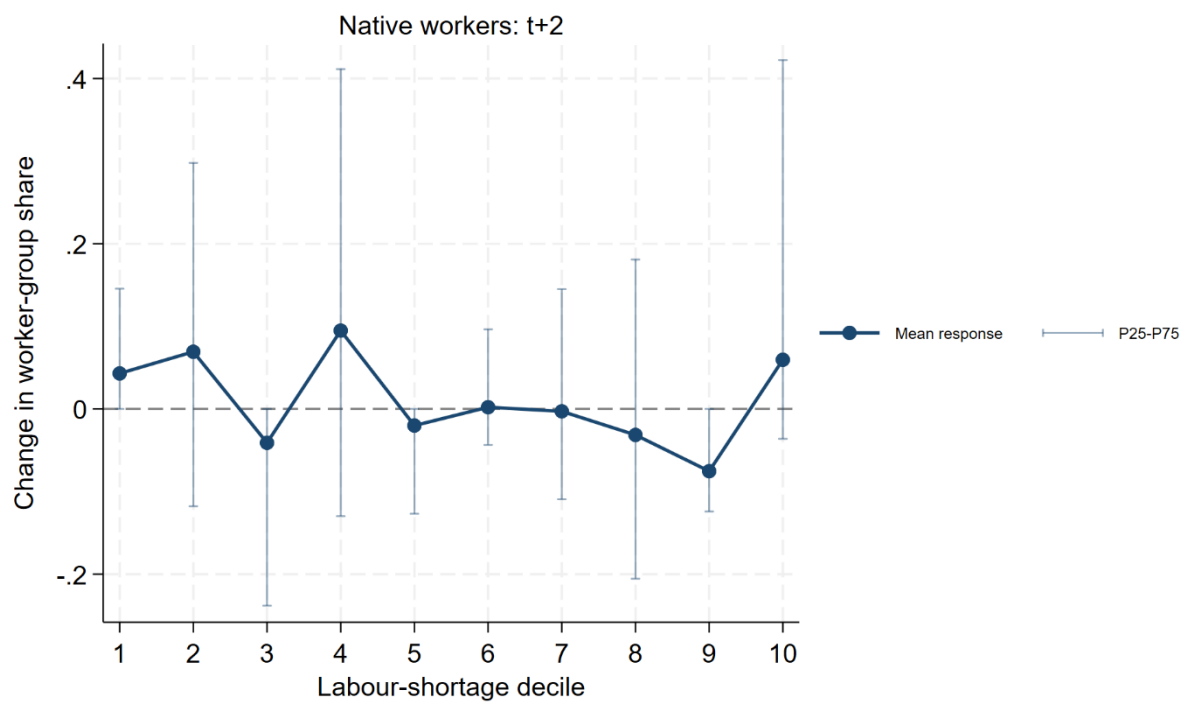
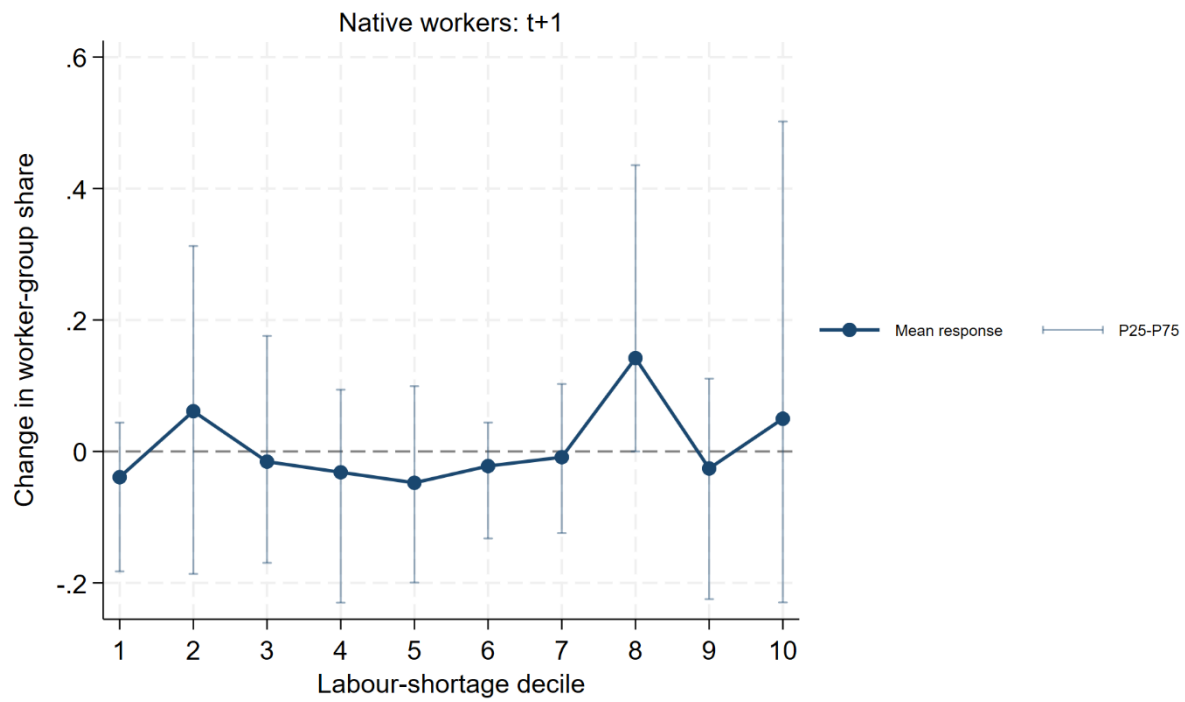
Appendix B: Change in worker group share by labour-shortage decile*

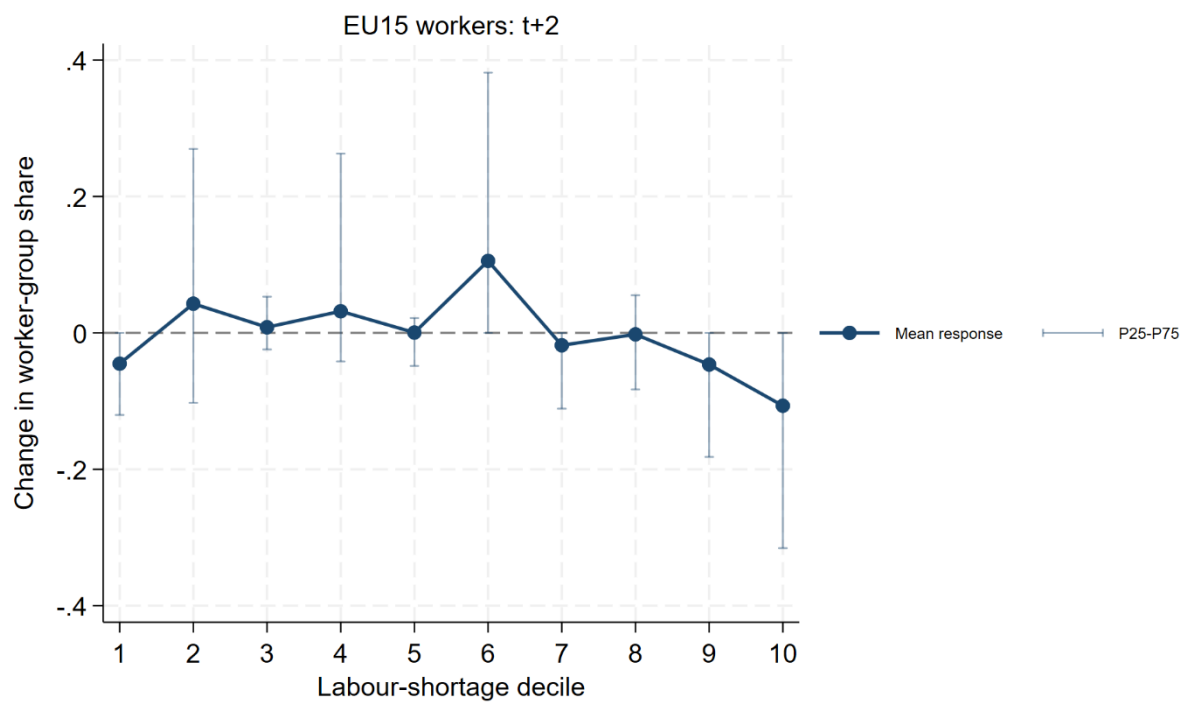
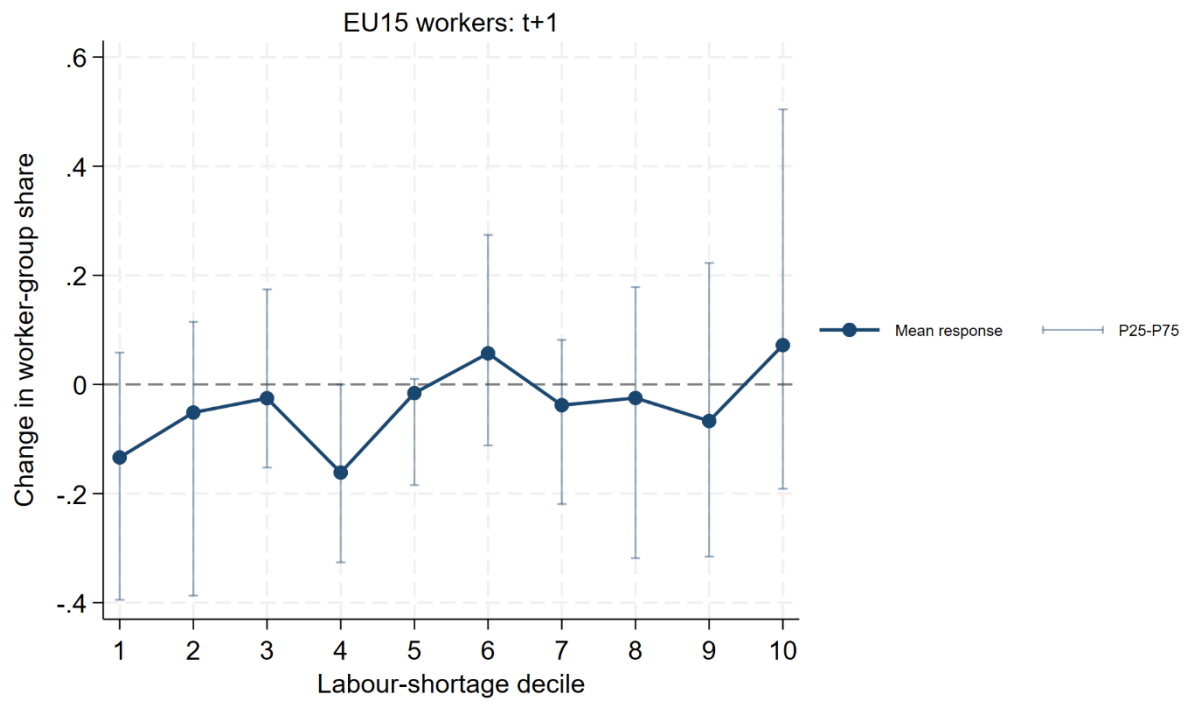
*The deciles are computed over the labour share values greater than 0.99

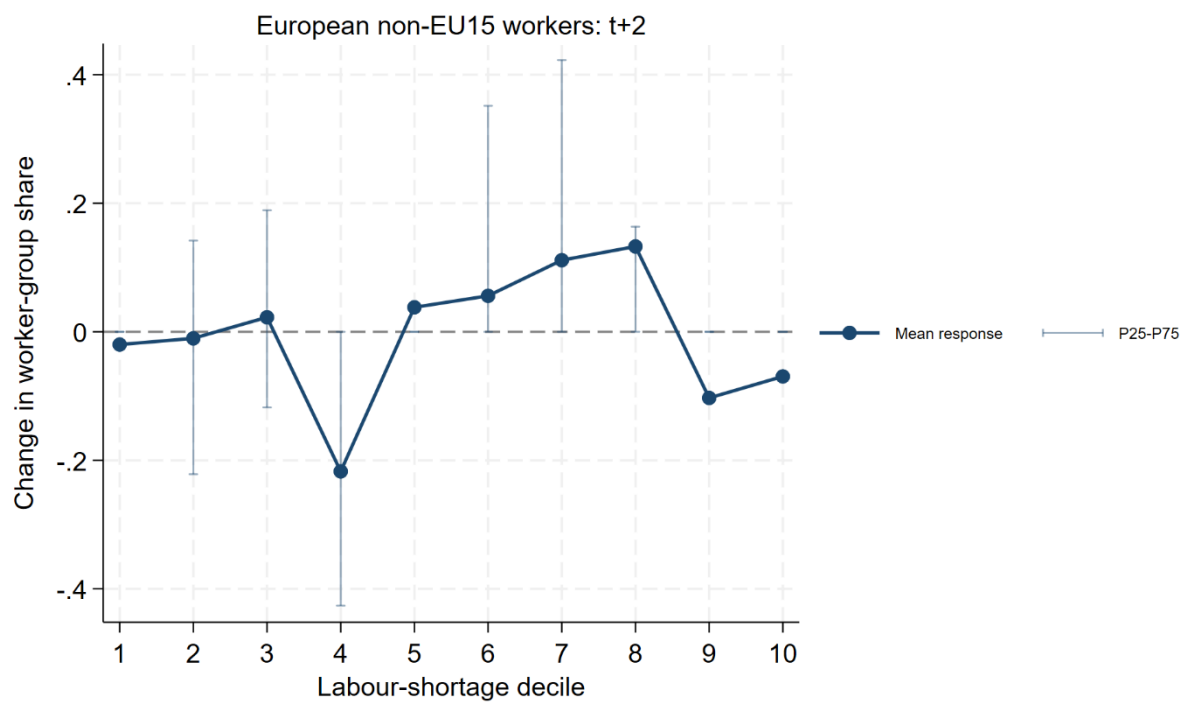
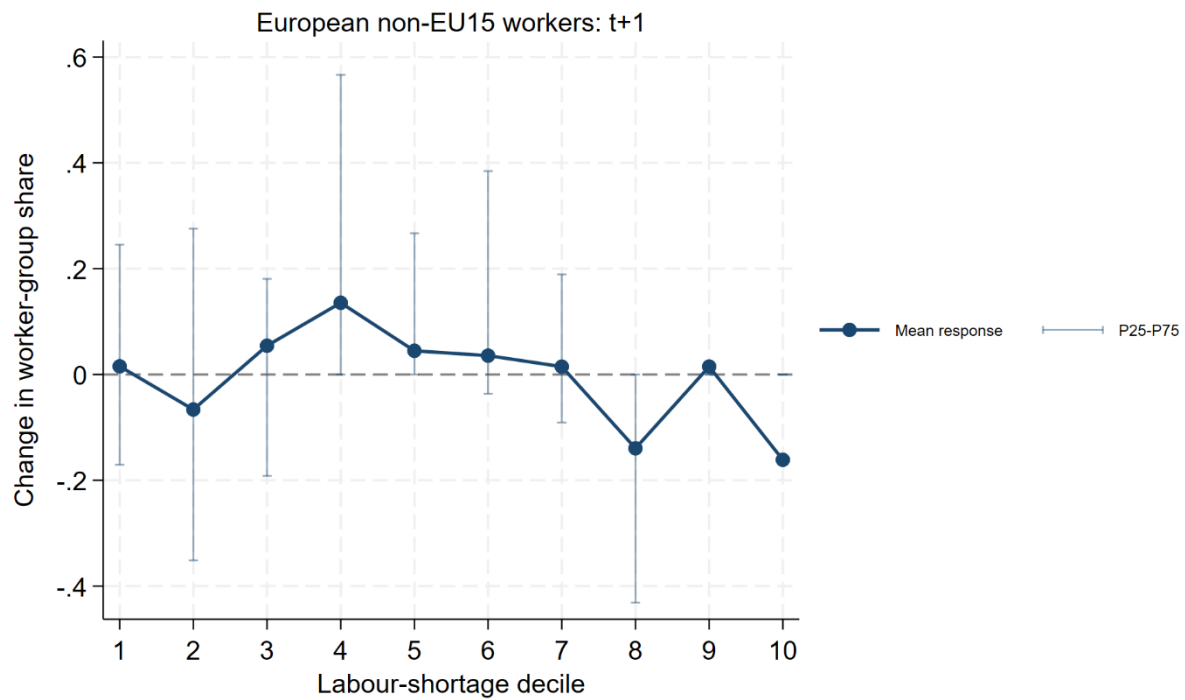




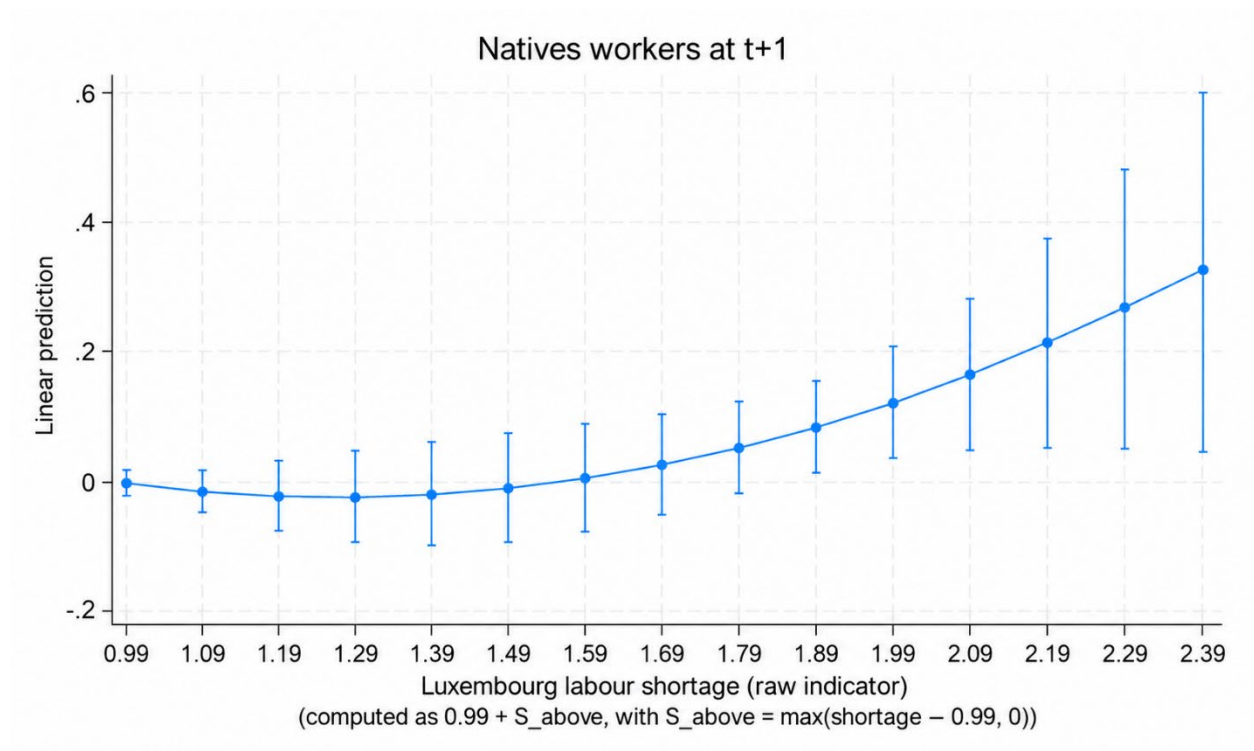
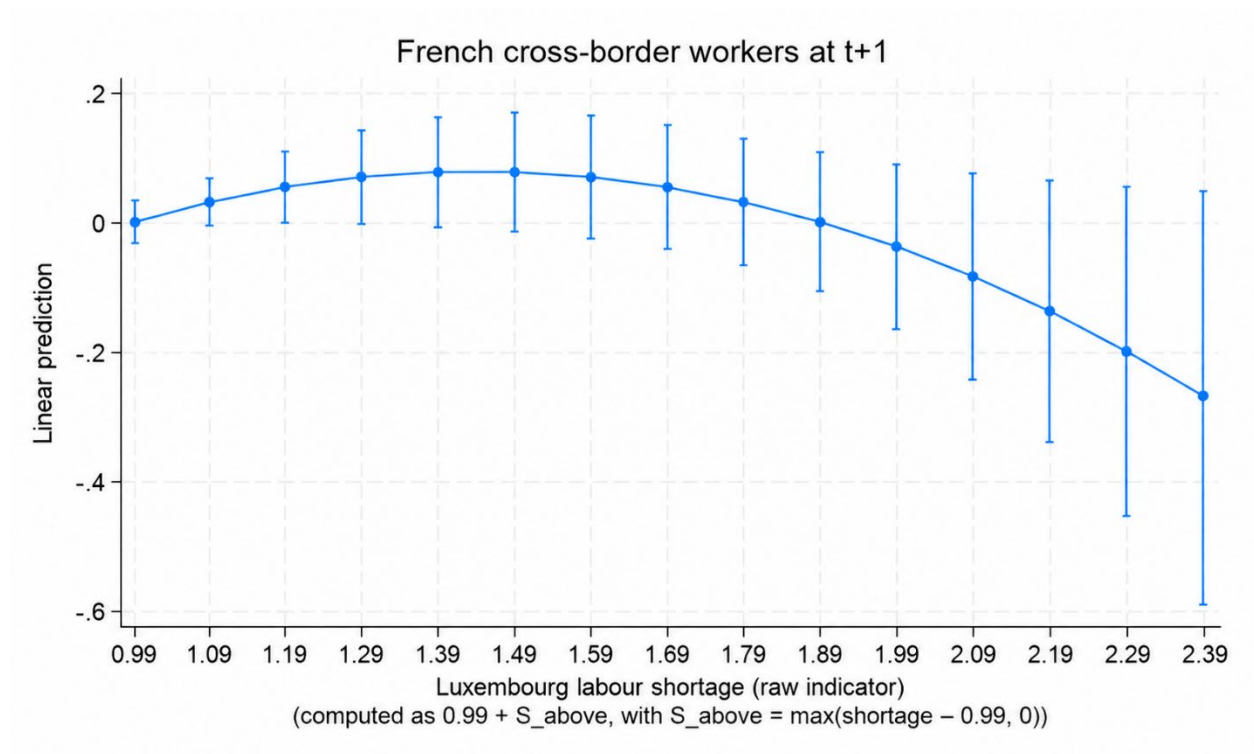


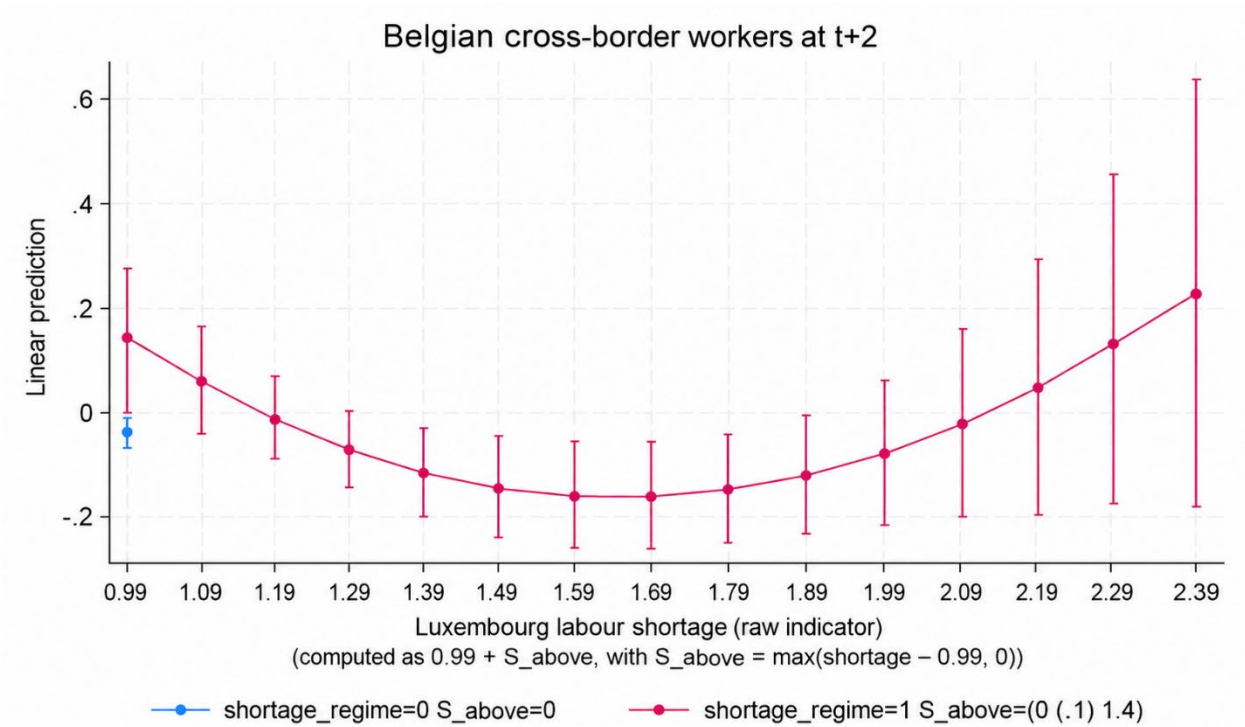
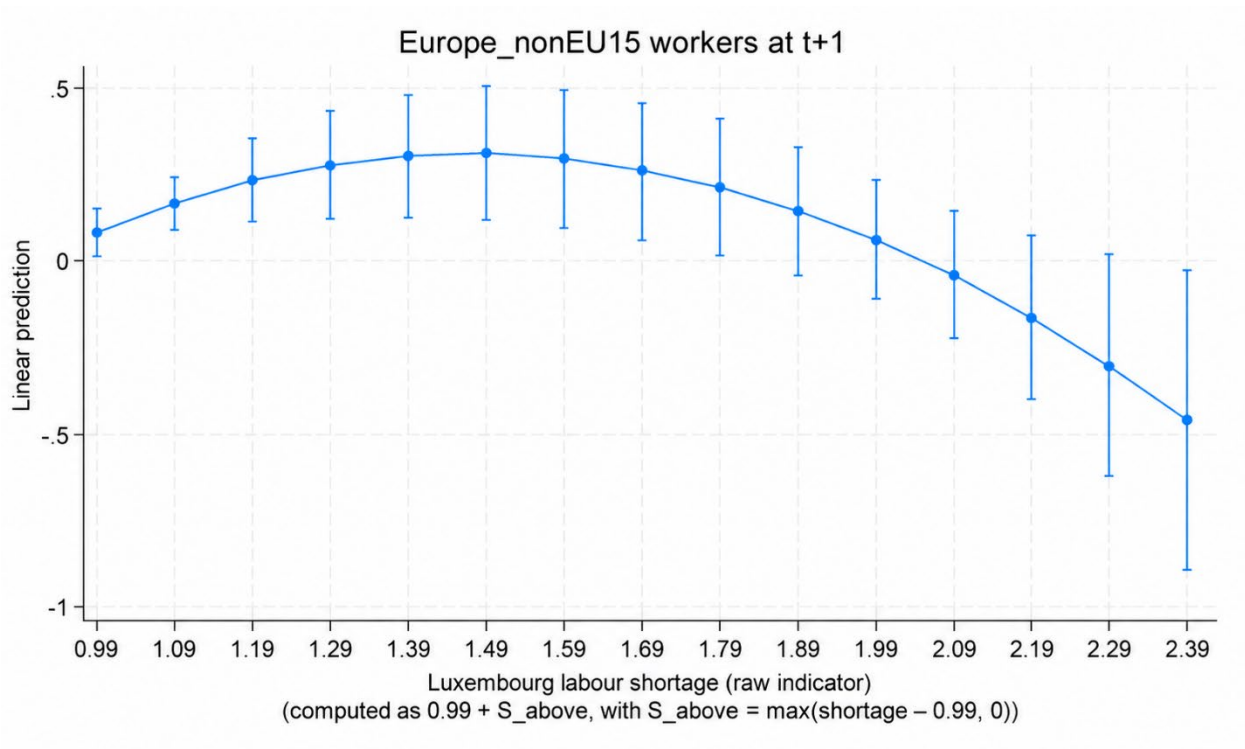


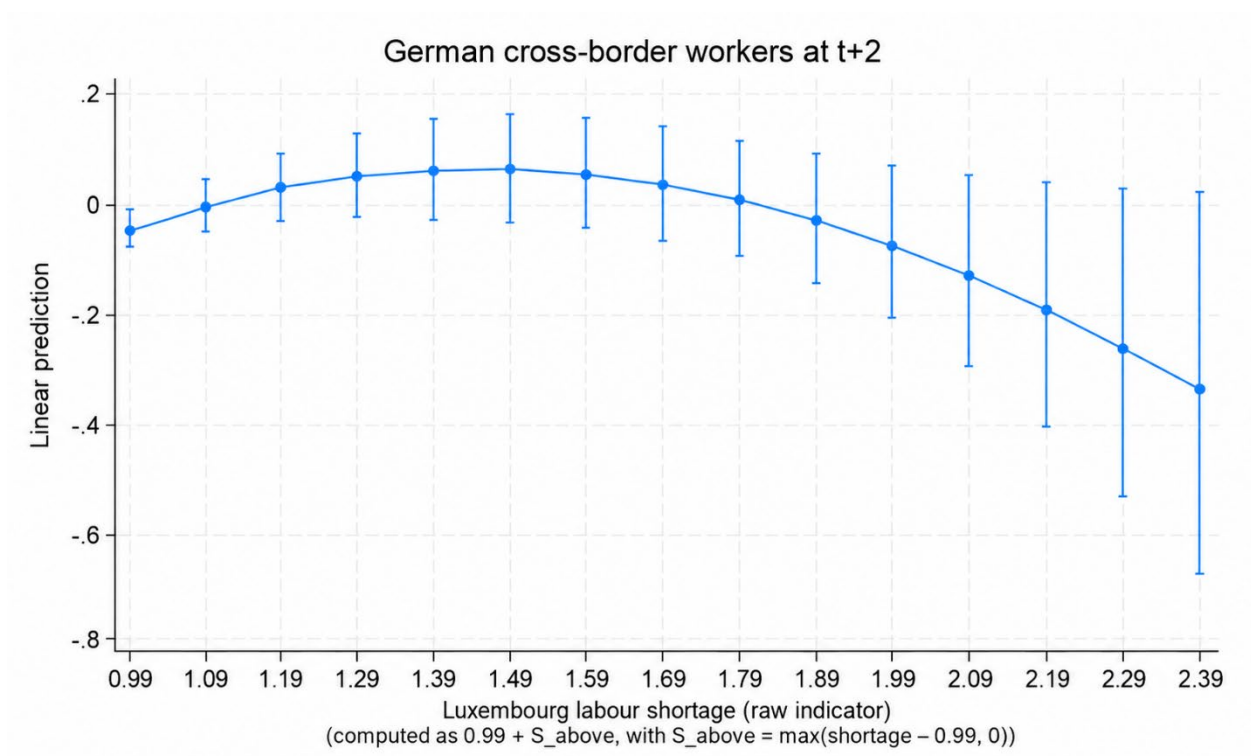




Appendix C: Margins of the fitted models







Appendix D: Does any additional variable or the induced sample composition affect the combined tests and then the relationship between labour shortage and the dependent variable examined

T+1 adjustments:

French CB workers in t+1, M1 Smooth response: joint S and S squared test

Extension	A			B			C		
	N	Wald/F	WCB	N	Wald/F	WCB	N	Wald/F	WCB
Age composition	770	0.510	0.520	589	0.142	0.148	589	0.148	0.144
Working conditions	589	0.148	0.144	562	0.034	0.031	562	0.031	0.030
Male median wage	589	0.148	0.144	589	0.148	0.144	589	0.149	0.146
Female median wage	589	0.148	0.144	553	0.265	0.265	553	0.288	0.289
Part-time share	589	0.148	0.144	474	0.122	0.144	474	0.120	0.139
Women share	589	0.148	0.144	491	0.111	0.099	491	0.120	0.109
ISCO2D fixed effects	589	0.148	0.144	589	0.148	0.144	589	0.200	0.189
Relative specialisation	589	0.148	0.144	574	0.165	0.164	574	0.166	0.164

Sample sizes and variables vary across extensions. A uses the original dataset, B and C the revised composition. C includes the additional variable as well.

Belgian CB workers in t+1, M1 Smooth response: joint S and S squared test

Extension	A			B			C		
	N	Wald/F	WCB	N	Wald/F	WCB	N	Wald/F	WCB
Age composition	770	0.714	0.719	589	0.745	0.758	589	0.739	0.752
Working conditions	589	0.739	0.752	562	0.645	0.657	562	0.639	0.659
Male median wage	589	0.739	0.752	589	0.739	0.752	589	0.717	0.727
Female median wage	589	0.739	0.752	553	0.882	0.884	553	0.730	0.736
Part-time share	589	0.739	0.752	474	0.708	0.731	474	0.706	0.728
Women share	589	0.739	0.752	491	0.959	0.962	491	0.978	0.978
ISCO2D fixed effects	589	0.739	0.752	589	0.739	0.752	589	0.959	0.959
Relative specialisation	589	0.739	0.752	574	0.753	0.765	574	0.714	0.725

Sample sizes and variables vary across extensions. A uses the original dataset, B and C the revised composition. C includes the additional variable as well.

German CB workers in t+1, M1 Smooth response: joint S and S squared test

Extension	A			B			C		
	N	Wald/F	WCB	N	Wald/F	WCB	N	Wald/F	WCB
Age composition	770	0.903	0.906	589	0.984	0.987	589	0.987	0.990
Working conditions	589	0.987	0.990	562	0.931	0.932	562	0.936	0.937
Male median wage	589	0.987	0.990	589	0.987	0.990	589	0.982	0.985
Female median wage	589	0.987	0.990	553	0.962	0.963	553	0.943	0.943
Part-time share	589	0.987	0.990	474	0.487	0.522	474	0.545	0.578
Women share	589	0.987	0.990	491	0.954	0.961	491	0.976	0.979
ISCO2D fixed effects	589	0.987	0.990	589	0.987	0.990	589	0.923	0.923
Relative specialisation	589	0.987	0.990	572	0.995	0.997	572	0.991	0.991

Sample sizes and variables vary across extensions. A uses the original dataset, B and C the revised composition. C includes the additional variable as well.

Luxembourg natives in t+1, M1 Smooth response: joint S and S squared test

Extension	A			B			C		
	N	Wald/F	WCB	N	Wald/F	WCB	N	Wald/F	WCB
Age composition	770	0.853	0.875	589	0.033	0.055	589	0.026	0.048
Working conditions	589	0.026	0.048	562	0.010	0.027	562	0.010	0.027
Male median wage	589	0.026	0.048	589	0.026	0.048	589	0.024	0.045
Female median wage	589	0.026	0.048	553	0.083	0.119	553	0.064	0.099
Part-time share	589	0.026	0.048	474	0.047	0.105	474	0.035	0.086
Women share	589	0.026	0.048	491	0.055	0.100	491	0.058	0.101
ISCO2D fixed effects	589	0.026	0.048	589	0.026	0.048	589	0.042	0.060

Sample sizes and variables vary across extensions. A uses the original dataset, B and C the revised composition. C includes the additional variable as well.

EU15 workers in t+1, M1 Smooth response: joint S and S squared test

Extension	A			B			C		
	N	Wald/F	WCB	N	Wald/F	WCB	N	Wald/F	WCB
Age composition	742	0.078	0.091	571	0.232	0.242	571	0.192	0.207
Working conditions	571	0.192	0.207	547	0.127	0.149	547	0.128	0.155
Male median wage	571	0.192	0.207	571	0.192	0.207	571	0.206	0.220
Female median wage	571	0.192	0.207	537	0.330	0.351	537	0.338	0.364
Part-time share	571	0.192	0.207	463	0.234	0.344	463	0.241	0.351
Women share	571	0.192	0.207	481	0.354	0.352	481	0.348	0.346
ISCO2D fixed effects	571	0.192	0.207	571	0.192	0.207	571	0.232	0.247

Sample sizes and variables vary across extensions. A uses the original dataset, B and C the revised composition. C includes the additional variable as well.

Non-EU15 European workers in t+1, M1 Smooth response: joint S and S squared test

Extension	A			B			C		
	N	Wald/F	WCB	N	Wald/F	WCB	N	Wald/F	WCB
Age composition	770	0.203	0.239	589	0.079	0.119	589	0.085	0.126
PCA	589	0.085	0.126	562	0.161	0.213	562	0.155	0.208
Male median wage	589	0.085	0.126	589	0.085	0.126	589	0.085	0.124
Female median wage	589	0.085	0.126	553	0.107	0.149	553	0.114	0.158
Part-time share	589	0.085	0.126	474	0.080	0.125	474	0.059	0.100
Women share	589	0.085	0.126	491	0.214	0.290	491	0.210	0.285
ISCO2D fixed effects	589	0.085	0.126	589	0.085	0.126	589	0.263	0.317

Sample sizes and variables vary across extensions. A uses the original dataset, B and C the revised composition. C includes the additional variable as well.

T+2 adjustments:

French CB workers in t+2, M1 Smooth response: joint S and S squared test

Extension	A			B			C		
	N	Wald/F	WCB	N	Wald/F	WCB	N	Wald/F	WCB
Age composition	770	0.033	0.055	589	0.242	0.287	589	0.222	0.261
Working conditions	589	0.222	0.261	562	0.310	0.353	562	0.334	0.385
Male median wage	589	0.222	0.261	589	0.222	0.261	589	0.221	0.259
Female median wage	589	0.222	0.261	553	0.207	0.250	553	0.202	0.243
Part-time share	589	0.222	0.261	474	0.117	0.140	474	0.091	0.111
Women share	589	0.222	0.261	491	0.114	0.134	491	0.111	0.129
ISCO2D fixed effects	589	0.222	0.261	589	0.222	0.261	589	0.042	0.066
Relative specialisation	589	0.222	0.261	574	0.255	0.300	574	0.297	0.345

Sample sizes and variables vary across extensions. A uses the original dataset, B and C the revised composition. C includes the additional variable as well.

Belgian CB workers in t+2, M2 Full response: joint jump, S and S squared test

Extension	A			B			C		
	N	Wald/F	WCB	N	Wald/F	WCB	N	Wald/F	WCB
Age composition	770	0.272	0.316	589	0.060	0.100	589	0.064	0.106
Working conditions	589	0.064	0.106	562	0.198	0.264	562	0.208	0.277
Male median wage	589	0.064	0.106	589	0.064	0.106	589	0.063	0.104
Female median wage	589	0.064	0.106	553	0.030	0.070	553	0.034	0.075
Part-time share	589	0.064	0.106	474	0.061	0.141	474	0.064	0.144
Women share	589	0.064	0.106	491	0.030	0.109	491	0.038	0.120
ISCO2D fixed effects	589	0.064	0.106	589	0.064	0.106	589	0.109	0.160
Relative specialisation	589	0.064	0.106	574	0.079	0.123	574	0.093	0.140

Sample sizes and variables vary across extensions. A uses the original dataset, B and C the revised composition. C includes the additional variable as well.

Belgian CB workers in t+2, M2 Shape: joint S and S squared test

Extension	A			B			C		
	N	Wald/F	WCB	N	Wald/F	WCB	N	Wald/F	WCB
Age composition	770	0.204	0.239	589	0.026	0.051	589	0.028	0.053
Working conditions	589	0.028	0.053	562	0.098	0.154	562	0.104	0.161
Male median wage	589	0.028	0.053	589	0.028	0.053	589	0.027	0.052
Female median wage	589	0.028	0.053	553	0.014	0.042	553	0.015	0.043
Part-time share	589	0.028	0.053	474	0.030	0.089	474	0.031	0.090
Women share	589	0.028	0.053	491	0.012	0.076	491	0.016	0.083
ISCO2D fixed effects	589	0.028	0.053	589	0.028	0.053	589	0.051	0.084
Relative specialisation	589	0.028	0.053	574	0.036	0.063	574	0.042	0.072

Sample sizes and variables vary across extensions. A uses the original dataset, B and C the revised composition. C includes the additional variable as well.

Belgian CB workers in t+2, M2 Threshold jump test in t+2

Extension	A			B			C		
	N	Wald/F	WCB	N	Wald/F	WCB	N	Wald/F	WCB
Age composition	770	0.295	0.297	589	0.027	0.032	589	0.029	0.034
Working conditions	589	0.029	0.034	562	0.061	0.070	562	0.065	0.076
Male median wage	589	0.029	0.034	589	0.029	0.034	589	0.026	0.031
Female median wage	589	0.029	0.034	553	0.033	0.041	553	0.029	0.036
Part-time share	589	0.029	0.034	474	0.014	0.019	474	0.014	0.019
Women share	589	0.029	0.034	491	0.035	0.044	491	0.038	0.047
ISCO2D fixed effects	589	0.029	0.034	589	0.029	0.034	589	0.055	0.062
Relative specialisation	589	0.029	0.034	574	0.038	0.044	574	0.035	0.041

Sample sizes and variables vary across extensions. A uses the original dataset, B and C the revised composition. C includes the additional variable as well.

German CB workers in t+2, M3 Recent period smooth response: joint S and S squared test

Extension	A			B			C		
	N	Wald/F	WCB	N	Wald/F	WCB	N	Wald/F	WCB
Age composition	548	0.015	0.025	492	0.026	0.053	492	0.027	0.052
Working conditions	492	0.027	0.052	471	0.037	0.077	471	0.031	0.064
Male median wage	492	0.027	0.052	492	0.027	0.052	492	0.027	0.053
Female median wage	492	0.027	0.052	463	0.049	0.084	463	0.040	0.071
Part-time share	492	0.027	0.052	401	0.032	0.082	401	0.034	0.083
Women share	492	0.027	0.052	410	0.039	0.100	410	0.050	0.121
ISCO2D fixed effects	492	0.027	0.052	492	0.027	0.052	492	0.073	0.092
Relative specialisation	492	0.027	0.052	477	0.021	0.043	477	0.025	0.051

Sample sizes and variables vary across extensions. A uses the original dataset, B and C the revised composition. C includes the additional variable as well.

Luxembourg natives in t+2, M1 Smooth response: joint S and S squared test

Extension	A			B			C		
	N	Wald/F	WCB	N	Wald/F	WCB	N	Wald/F	WCB
Age composition	770	0.093	0.184	589	0.238	0.261	589	0.211	0.236
Working conditions	589	0.211	0.236	562	0.205	0.273	562	0.174	0.232
Male median wage	589	0.211	0.236	589	0.211	0.236	589	0.220	0.244
Female median wage	589	0.211	0.236	553	0.400	0.419	553	0.364	0.384
Part-time share	589	0.211	0.236	474	0.529	0.565	474	0.490	0.532
Women share	589	0.211	0.236	491	0.792	0.798	491	0.798	0.806
ISCO2D fixed effects	589	0.211	0.236	589	0.211	0.236	589	0.190	0.202

Sample sizes and variables vary across extensions. A uses the original dataset, B and C the revised composition. C includes the additional variable as well.

EU15 workers in t+2, M2 Full response: joint jump, S and S squared test

Extension	A			B			C		
	N	Wald/F	WCB	N	Wald/F	WCB	N	Wald/F	WCB
Age composition	764	0.558	0.611	587	0.216	0.267	587	0.181	0.230
Working conditions	587	0.181	0.230	560	0.348	0.448	560	0.292	0.403
Male median wage	587	0.181	0.230	587	0.181	0.230	587	0.181	0.230
Female median wage	587	0.181	0.230	551	0.212	0.281	551	0.164	0.229
Part-time share	587	0.181	0.230	474	0.328	0.424	474	0.341	0.438
Women share	587	0.181	0.230	489	0.238	0.347	489	0.278	0.389
ISCO2D fixed effects	587	0.181	0.230	587	0.181	0.230	587	0.194	0.229
Age composition	764	0.558	0.611	587	0.216	0.267	587	0.181	0.230

Sample sizes and variables vary across extensions. A uses the original dataset, B and C the revised composition. C includes the additional variable as well.

EU15 workers in t+2, M2 Shape: joint S and S squared test

Extension	A			B			C		
	N	Wald/F	WCB	N	Wald/F	WCB	N	Wald/F	WCB
Age composition	764	0.358	0.407	587	0.120	0.147	587	0.095	0.122
Working conditions	587	0.095	0.122	560	0.212	0.292	560	0.208	0.292
Male median wage	587	0.095	0.122	587	0.095	0.122	587	0.094	0.122
Female median wage	587	0.095	0.122	551	0.117	0.163	551	0.102	0.146
Part-time share	587	0.095	0.122	474	0.223	0.319	474	0.235	0.332
Women share	587	0.095	0.122	489	0.157	0.271	489	0.180	0.302
ISCO2D fixed effects	587	0.095	0.122	587	0.095	0.122	587	0.111	0.134

Sample sizes and variables vary across extensions. A uses the original dataset, B and C the revised composition. C includes the additional variable as well.

EU15 workers in t+2, M2 Threshold jump test

Extension	A			B			C		
	N	Wald/F	WCB	N	Wald/F	WCB	N	Wald/F	WCB
Age composition	764	0.360	0.374	587	0.136	0.150	587	0.105	0.119
Working conditions	587	0.105	0.119	560	0.161	0.203	560	0.193	0.234
Male median wage	587	0.105	0.119	587	0.105	0.119	587	0.102	0.116
Female median wage	587	0.105	0.119	551	0.129	0.144	551	0.156	0.173
Part-time share	587	0.105	0.119	474	0.226	0.291	474	0.230	0.295
Women share	587	0.105	0.119	489	0.231	0.299	489	0.235	0.303
ISCO2D fixed effects	587	0.105	0.119	587	0.105	0.119	587	0.139	0.153

Sample sizes and variables vary across extensions. A uses the original dataset, B and C the revised composition. C includes the additional variable as well.

Non-EU15 European workers in t+2, M6 Temporal change: joint change in jump, slope and curvature

Extension	A			B			C		
	N	Wald/F	WCB	N	Wald/F	WCB	N	Wald/F	WCB
Age composition	770	0.586	0.615	589	0.029	0.087	589	0.020	0.070
Working conditions	589	0.020	0.070	562	0.018	0.069	562	0.020	0.078
Male median wage	589	0.020	0.070	589	0.020	0.070	589	0.020	0.069
Female median wage	589	0.020	0.070	553	0.020	0.078	553	0.020	0.076
Part-time share	589	0.020	0.070	474	0.092	0.249	474	0.092	0.252
Women share	589	0.020	0.070	491	0.036	0.135	491	0.034	0.131
ISCO2D fixed effects	589	0.020	0.070	589	0.020	0.070	589	0.027	0.092

Sample sizes and variables vary across extensions. A uses the original dataset, B and C the revised composition. C includes the additional variable as well.

Non-EU15 European workers in t+2, M6 Expanded response: baseline jump plus temporal changes

Extension	A			B			C		
	N	Wald/F	WCB	N	Wald/F	WCB	N	Wald/F	WCB
Age composition	770	0.405	0.439	589	0.025	0.069	589	0.021	0.061
Working conditions	589	0.021	0.061	562	0.023	0.070	562	0.030	0.087
Male median wage	589	0.021	0.061	589	0.021	0.061	589	0.021	0.061
Female median wage	589	0.021	0.061	553	0.023	0.071	553	0.024	0.074
Part-time share	589	0.021	0.061	474	0.126	0.284	474	0.128	0.294
Women share	589	0.021	0.061	491	0.049	0.142	491	0.046	0.136
ISCO2D fixed effects	589	0.021	0.061	589	0.021	0.061	589	0.031	0.088

Sample sizes and variables vary across extensions. A uses the original dataset, B and C the revised composition. C includes the additional variable as well

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