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ORIGINAL ARTICLE

Open Access

The effect of labour tightness on wages at the regional level in Central Europe

Lajos Tamás Szabó^{1*}D

Abstract

I estimate the effect of tightness on wages in Hungary and Slovakia. The Mortensen Pissarides model predicts a positive relationship but the empirical evidence is scarce. I instrument tightness by the distance of a district from the Austrian border, interacted with a dummy that marks the opening of the Austrian labour market to these countries in 2011. I find a positive effect of tightness on wages, which is in line with the conclusion of the models. If tightness increase by 1 per cent than ceteris paribus wages increase by roughly 0.2 per cent both in Hungary and Slovakia as well.

Keywords Local labour markets, Labour market tightness, Wage equation

JEL Classification 131, J61, J63, J64

1 "Introduction"

"for the labourer is worthy of his hire" 18 Luke 10:7 Estimating migration effects on wages in both sending and receiving countries is a popular and important topic in labour economics. There is a large amount of evidence that the number of newcomers has a negative effect on native workers' wages (see the early works by Altonji and Card (1991), Card (2001), Angrist and Kugler (2003), Borjas (2003) and, more recent ones by Dustmann et al. (2017), Edo and Rapoport (2019), Monras (2020)), especially among low-skilled employees. On the other hand, there are studies, which find a non-significant effect (e.g. Boustan et al. (2010), Dustmann et al. (2005)) or even positive effect (e.g. Dustmann et al. (2012)). In their meta-analysis Dustmann et al. (2016) find that the literature on the impact of immigration is inconclusive. The situation in the sending countries is less covered. The few existing papers (Mishra (2007), Aydemir and Borjas (2007) and Dustmann et al. (2015)) find that emigration has a positive effect on wages in the sending countries due to the decreasing labour supply.

In 2011, all administrative obstacles for Hungarians to work in Austria were removed. Data from the Austrian authorities show that the number of Hungarians tripled over a period of five years, with these Hungarian workers concentrated along the Austrian- Hungarian border. In some parts of these areas, the share of Hungarians out of the total number of employees reaches 35 per cent. This negative labour supply shock in Hungary makes it possible to estimate the effect of tightness (the ratio of vacancies to unemployment) on wages. If a Hungarian employee starts working in Austria it means one new vacancy in Hungary, which increases the labour market tightness. If an unemployed Hungarian finds a job in Austria tightness also increases.¹

From a theoretical standpoint, the Mortensen-Pissarides model (Mortensen (1982), Pissarides (2000)) predicts

¹ In principle, inactive people can also go to work in Austria, in which case

tightness does not change. On the other hand, this is not likely to be a large

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flow.

that tightness has a positive effect on wages. The identification issue is the endogeneity of tightness in the wage equation. There are very few empirical papers that estimate this effect because the scarcity of detailed vacancy and unemployment data and the lack of exogenous variation (Bossier and Popp (2024)). The existing results (Harmon (2013), Hoeck (2022) and Bossier and Popp (2024)) are not conclusive. Harmon (2013) obtains ambiguous results on the sign and magnitude of the parameter of tightness in the wage equation. Hoeck (2022) estimated a positive relationship. Bossier and Popp (2024) find a small positive effect. In their full-scale macroeconomic model, both Shimer (2005) and Hagedorn and Manovskii (2008) calibrated a positive parameter for tightness in the wage equation. There are other papers, which measure the tightness differently, e.g. the ratio of unemployed to employed (Brunow et al. (2022)) due to lack of vacancy data.

To overcome the endogeneity issue, I use instrumental variables (IVs) to estimate the effect of tightness on wages. In this paper, I use annual district-occupational level data from Hungary. Districts can be considered as local labour markets. An average district has a bigger town and some villages or smaller towns. Data availability for the Hungary and Slovakia is different, and therefore I consider the Slovakian estimate as a robustness check for the Hungarian results. My IV is the interaction of a district's distance to the Austrian border with a dummy variable that indicates the opening of the Austrian labour market in 2011 (and thereafter). The commuting cost to Austria is low in the districts along the western border. Due to workers commuting from these regions, labour supply is lower, and thus tightness is higher. A similar measure of IV was used before in the literature: Dustmann et al. (2017) used the distance from the German border to instrument the number of Czech workers in Germany (in the receiving country). I use the distance from the border and the opening of the Austrian labour market as an IV for tightness in the sending country. The negative labour supply shock makes it possible to estimate the effect of tightness on wages.

There are potential threats to the validity of the instrument. First, tightness is correlated with development, and the distance from Austria is also correlated with the development level of the districts. To overcome these issues, I control for development by using district-occupational level fixed effects. Furthermore, I use only the north-western districts, which are the most developed in Hungary. As a result, the sample contains districts with a similar development level. Another potential threat to validity may be an increase in trade between Austria and Hungary, which could affect labour market outcomes as well. According to trade data, there was no extensive change in trade after 2011 and the share of Hungarian exports to Austria did not change much either.

Estimating a panel IV model, I obtain positive parameter estimates for the tightness effect with a reasonable magnitude. If tightness grows by 1 per cent then wages increase by 0.23 per cent. Decomposing the wage growth to observable factors, the change in tightness contributed roughly 25% of the wage growth. Robustness checks show that the result is quite stable, but it is concentrated in blue-collar occupations, which is intuitive since 75 per cent of Hungarian employees in Austria work in bluecollar jobs.

As a robustness check, I use Slovakian data as well. The district-occupational level data are not available for the whole period and therefore I need to interpolate it for the 2009–2011 period. The number of Slovakian workers in Austria also rose considerably after 2011, and they are also concentrated in regions along the border. The parameter estimate for the tightness is slightly lower, but the quantitative conclusion is similar to the Hungarian case. The estimated coefficient is 0.18, which means that in the case of a 1 per cent increase in tightness the wage increases by 0.18 per cent.

In their seminal work, Blanchflower and Oswald (1995) argue that local unemployment has an effect on wages, which is considered as an 'empirical law of economics'. In their work, they use the unemployment rate for locations and industries in the US. They find that if unemployment decreases by 1 per cent then wages increase by 0.1 per cent. The authors find similar results in their later work (Blanchflower and Oswald (2005)) as well. My paper differs from their work in a number of aspects. On the one hand, the wage curve can be considered as an empirical rule of thumb, not a causal relationship. My identification strategy makes it possible to estimate a causal relationship between tightness and wages. On the other hand, I use the ratio of vacancies to unemployment instead of the unemployment rate. Furthermore, my specification makes it possible to directly test the implication of the Mortensen-Pissarides model. Wage curve estimations exist for Hungary as well. Studies (such as Kertesi and Köllő (1997), Kertesi and Köllő (1999), Delteil et al. (2004), Nobilis (2011) and Csáfordi (2014)) find similar results as Blanchflower and Oswald (1995).

The paper makes four contributions to the existing literature. First, I empirically estimate the tightness coefficient in the wage equation and confirm the prediction of the Mortensen-Pissarides model. My contribution is to directly identify the effect of tightness on wages from regional and occupational heterogeneity using data from two Central European countries.

Second, I contribute to the existing literature on the wage effects of emigration. The larger part of this

literature focuses on the wage effect in the receiving countries, while a smaller part concentrates on the sending countries; my research fits into the latter category.

Third, my results empirically confirm the sign of the tightness parameter in recent full-scale macroeconomic models (e.g. in Shimer (2005) and Hagedorn and Manovskii (2008)).

Fourth, my findings can be used in policy making, for instance in the case of monetary policy or designing the state budget. Since wages are a major determinants of cost-push inflation, the effect of tightness on wages is important in an inflation targeting monetary policy framework. Personal income tax constitutes one of the largest revenue for the state budget, which is another reason why tightness plays a role in public policy.

The rest of the paper is organised as follows. In Sect. 2 I summarise a modified version of the Mortensen-Pissarides search and matching model focusing on the wage equation. The identification method is elaborated in Sect. 3. The data sources and the estimated equations can be found in Sect. 4. I draw the conclusion in Sect. 5.

2 Theoretical framework in brief

I briefly summarize a modified version of Mortensen-Pissarides model (Pissarides (2000)) or as it is also known the search and matching theory based on Roshchina (2016).

In this framework, firms can only produce using capital and labour together. Jobseekers look for an unfilled vacancy. If a vacancy and an unemployed person are matched, a productive job is created. It is costly (in terms of time and other resources) both for the firm and for the unemployed to find a suitable match. This search time generates frictional unemployment. One of the key concepts in this model is that the probability of matching depends on the ratio of vacancies to the number of unemployed. This ratio is called labour market tightness. In this model, job creation and destruction are independent of market shocks, which is why there are unemployed who are in search of new jobs.

Labour supply is the sum of the employed and unemployed. For the jobseeker, the return on being unemployed is the unemployment benefit plus the expected value of finding a job. For the employee, the return on employment is equal to his wage and the expected value of losing the job.

Labour demand consists of the filled jobs and the vacancies. Each firm has a flow revenue from production, which is given and can only decide on the number of posted vacancies. For the firm, the flow return on a vacancy is the expected gain of finding a suitable worker and the cost of posting the vacancy, while the value of a filled job is the profit (the difference between revenue and wage) plus the expected value of the job becoming vacant.

The wage is determined using a Nash bargaining method. When a job seeker fills a vacancy both the worker and the firm are better off and a surplus is generated. The total surplus is divided between the worker and the firm. The equilibrium wage is:

$$w = \beta \left(y + \gamma_0 \theta \right) + (1 - \beta)z \tag{1}$$

where.

- β is the bargaining power of the worker,
- *y* is the production of the firm,
- γ_0 is the cost of an open vacancy, i.e. the cost of the time and resources (e.g. advertising costs) used to find a suitable employee,
- θ is the labour market tightness,
- *z* is the unemployment benefit, i.e. the outside option of the worker.

This means that the wage is the convex combination of the unemployment benefit and the firm's surplus. The firm's surplus is the sum of the output and the expected cost savings if the firm fills the vacancy. If tightness increases, the probability of filling a vacancy diminishes, and consequently, it raises the rents of a filled vacancy. It follows from this mechanism that with the increase in tightness wages also rise. It is also worth mentioning that labour market conditions only affect the wage through θ . Therefore, unemployment (rate) alone does not affect wages, and it is only the ratio of vacancies to unemployment which matters. This is because wages are determined in the Nash bargaining process after the firm meets the job seeker. Tightness determines not only how long a vacancy is open, but also the expected cost to search for an employee. I estimate Eq. (1) by panel IV method.

My focus is on the tightness parameter ($\beta\gamma_0$) but it is worth noting that there are modified versions of the Mortensen-Pissarides model (e.g. Shimer (2005), Hall and Milgrom (2008), Diamond (2011), Ortego-Marti (2017)). These papers argue that unemployment and vacancies are more volatile in the US data than in the model and they present different modifications to the model.

3 Identification method

I wish to estimate the effect of labour tightness on wages. The main issue here is that not only tightness has an effect on wages, as wages also affect tightness. The reverse causality affects both the number of vacancies and the number of unemployed.



Fig. 1 Number of Hungarian and Slovakian citizens working in Austria. Source: Austrian Social Security Database

If tightness increases, it raises recruitment frictions for firms, which results in higher wages. On the other hand, rising wages mean that the outside option (unemployment benefit) is less desirable. Higher wages can attract inactive people to the labour market. First, these people become unemployed and later can find a job. This process results in a rising number of unemployed, which means that tightness decreases.

The feedback effect also affects labour demand. If wages are higher, posting vacancies is more costly to firms. This leads to a lower number of vacancies, which means lower labour market tightness. These two channels imply that the naive OLS estimations result in downward-biased estimates.

In an ideal thought experiment, some districts would be randomly chosen, where an exogenous negative labour supply shock occurs (e.g. a decrease in the retirement age or an increase in compulsory school leaving age). Due to this shock, labour market tightness increases (e.g. some unemployed and some workers retire and therefore the number of unemployed falls). This increase has an effect on wages, which can be measured because there are districts, where there is no such change.

The external negative labour supply shock is the opening of the Austrian labour market in 2011 for the newly joined members of the European Union. Before 2011 there were restrictive policies with a quota for foreign workers in Austria. Therefore, it was possible to work in Austria before 2011 from the newly joined member states for a limited number of people (which corresponds to the modest increase in employees before 2011). After 2011, all administrative obstacles were removed for the citizens of the newly joined member states to work in Austria.

There was a personal income tax reform in Hungary in 2011. The tax rate was lowered and a flat rate was introduced instead of progressive tax rate. Altogether this was favourable for employees, and therefore it did not lead to increasing migration intentions. Furthermore, it was universal across the country so distance from the Austrian border does not correlate with it. That is why these reforms cannot violate the exogeneity assumption.

In an ideal case, there would be a database on the origins of the Hungarian workers in Austria at the district level. In such a case, I could easily calculate the size of the labour supply shock in each Hungarian district due to the opening of the Austrian labour market. As I do not have this information, I use distance from the Austrian border as an instrumental variable. Living closer to Austria means that the cost of commuting is smaller. The exact IV is the interaction of the distance and the after 2010 dummy.

In 2011 the dynamics of the number of Hungarians working in Austria rose considerably (see Fig. 1). Based on the Austrian Social Security Database the highest share of Hungarian employees is found along the border (Fig. 2). Although the place of residence is not known in this database, one can suppose that closer to the border Hungarians commute to work in Austria since living expenses are lower in Hungary than in Austria.

The Hungarian Labour Force Survey (LFS) ² contains some of the employees in other countries. It contains

 $^{^{\}overline{2}}$ The LFS is a representative survey, covering 36,000 households. The main aim of the survey is to provide information on the Hungarian labour market.



Fig. 2 Proportion of Hungarian workers in Austria by municipality 2011–2015. Source: Schmieder (2019) p. 102. (Austrian Social Security Database)

Regions in which all the districts are in the sample (closer than 3 h to the Austrian border): Bratislava, Nitra, Trencín and Trnava. Regions in which not all the districts are in the sample: Banska Bystrica and Zilina (marked by grey on the graph). Those regions are also marked grey, where there are no districts, which are in the sample



Fig. 3 Austria, Hungary and Slovakia

those emigrated workers who can be considered as crossborder commuters. They have a household member in Hungary who can answer the LFS questionnaire instead of the emigrated worker. The LFS does not contain those who (temporarily) migrated to another country with their whole family. Based on the LFS, in 2011 there were 20,800 Hungarians who worked in Austria, which was 32 per cent of the total number of cross-border commuters from Hungary. In 2015, the number of commuters to Austria increased to 58,000, which was 43 per cent of the covered cross-border commuters in the LFS. 75 per cent of those, who were commuters to Austria lived in the Western-Transdanubia and Central-Transdanubia regions,³ which are the closest to Austria. This suggests

 3 The LFS does not have district-level decomposition, and is not representative on this level, which is why I cannot use it as a key variable in my research.

that my IV is strong in the west of Hungary, which is also confirmed by the estimation results. For more details on commuters in the Hungarian LFS, see Bodnár and Szabó (2014).



Fig. 4 Districts included in the main specification. Red: included districts, yellow: not included districts



Fig. 5 Tightness before and after 2011 in the counties of Hungary. note: Counties, in which all the districts are in the sample (closer than 3 h to the Austrian border): Győr- Moson-Sopron, Vas, Zala, Veszprém, Komárom-Esztergom, Fejér, Budapest. Counties, in which not all the districts are in the sample: Somogy and Pest (marked by grey on the graph as the other counties). Those countries are also marked grey, where there are no districts, which are in the sample

The number of Slovakian citizens working in Austria has also been growing rapidly since the labour market opening in 2011 (see Fig. 1). According to the Austrian Social Security database, the number of Slovakian citizens, who worked in Austria was around 10,000 at the beginning of 2011 and had tripled by the end of 2016, as in the Hungarian case. Both Hungary and Slovakia have a common border with Austria (see Fig. 3).

There can be potential threats to the IV's validity. The distance from Austria is correlated with development since the more developed districts are in the west of the country in Hungary (and in Slovakia as well). Wages are also higher in developed districts. This phenomenon can violate the exogeneity assumption. Therefore, I have to control for development, for which I use district-occupational level fixed effects. Another type of control is the number of districts selected for the estimation. In the main specification, the whole country is not included, only the districts which are closer than 3 h by car to Austria. For Hungary, only the north-western districts are included (see Fig. 4). The number of included districts is 66 out of the total of 175. The population of these districts is 50.6 per cent of the country's population. These districts are more similar to each other in development than the rest of the country. In fact, they are the most developed regions of the country. The big development difference is between the east and northeast part of the country and these districts.

Tightness rose more than the national average in those counties, ⁴ which are closer to the Austrian border than

3 h. There was a tightness increase in all counties, but the tightness increase was more robust in counties which are closer to the border (Fig. 5).

Another threat could be that after 2011 trade increased rapidly between Austria and Hungary, which could affect Hungarian wages. The change after 2011 is not considerably larger than any other change between 2006 and 2019 (see Fig. 6). The increase in trade after 2009 is due to the recovery following the financial crisis. After Hungary joined the EU in 2004 all trade barriers were removed between the two countries and thus there have not been any administrative changes in trade since then. In period 2006–2019, on average, the share of Austrian exports to Hungary out of total Austrian exports was 3.1 per cent, while the share of Hungarian exports to Austria out of total Hungarian export was 5.6 per cent. These shares did not change much during 2006–2019.

Another potential threat could be that those firms experiences a positive productivity shock, which are closer to Austria. This would lead to higher wages in those cases, where the firm is closer to the border. To overcome this issue, I estimated the IV on individual level, where I included individual-level FEs as well (see Appendix E). These FEs also absorb these type of shocks.

4 Results and discussion

4.1 Description of the Hungarian data

There have been considerable changes in the Hungarian labour market since the financial crisis a decade and a half ago. The number of unemployed has decreased significantly and vacancies have increased. On the other hand, these changes did not occur evenly across the regions of the country. The western parts are characterised by a considerable labour shortage, while in the east

⁴ A county is a larger administrative unit in Hungary. There are 20 counties in Hungary (including the capital city). A county contains 6–18 districts. The counties correspond to NUTS 3 level local administrative units. It is more transparent to graph 20 lines instead of 175 that is why I graph counties instead of districts on Fig. 5



Fig. 6 Trade between Hungary and Austria. Including goods and services. Source: UNCTAD



Fig. 7 Logarithm of tightness at the district level (2012). Average district level tightness. Source: NES

the number of vacancies has not risen much. At the same time, there have been other structural changes as well. In 2011, Austria (and other member states) opened its labour market to the recently joined EU-member states. The local labour market for those living close to the Austrian border thus expanded significantly. This change exacerbated the labour shortage in the western parts of the country. Although the overall labour market situation seems to be improving, the spatial pattern has not changed much.

To calculate tightness, I use data from the National Employment Service (NES). Both unemployment and vacancy statistics are available at the settlement level, and thus I was able to aggregate the data to the district *(járás)* level (Fig. 7). There is a visible connection between tightness and private sector wages at the district level (see Figs. 7 and 8). Hungary has 175 districts, with the capital



Fig. 8 Average log private sector gross wages at the district level (2012)

city considered as one district. The data are available monthly, which I average annually. Firms must report their vacancies to the Employment Service, although there is no sanction if they do not do so. I use only nonsubsidized vacancy data, as I would like to measure the effects of market forces (vacancies of the public work programme are thus excluded). The vacancies are available on a two-digit occupational level, which I can use to construct occupational level tightness.

The unemployment data consist of the number of those who have registered at the local jobcentre. ⁵ Only those

⁵ Ideally the number of those, who are employed but currently searching for a new job should also be in the denominator of tightness. The data of onthe-job-searchers is only available in Hungary in the Labour Force Survey (LFS), which is not representative at the district level that is why I cannot use it.

who are unemployed, can register at job centres. The highest education level of the registered unemployed is available, which can be used when calculating occupational-level tightness (see Appendix A.l for details of the calculations).

The outcome variable is the district two-digit, occupational-level average wage. The source of this data is the Hungarian State Treasury (HST) administrative dataset, which contains every individual for whom the employer paid pension contribution. I averaged the private sector wages in every district two-digit occupational cell weighting by the employment time.

To calculate district two-digit occupational cell nominal average monthly wages, I selected individuals, who had any kind of employment in the private sector on 30th April in each year (between 2009 and 2017). In this way, I can overcome the seasonality issues. The Hungarian administrative database contains all persons for whom the employer pays pension contributions. This means that every type of employment is included (e.g. part-time work, self-employment etc.). As there are many individuals, who have several types of jobs, I choose the highest wage for everyone. I calculated the district two-digit occupational cell full-time equivalent (fte) wage for every year using the highest wage for each individual. There are 175 districts in Hungary (the capital is counted as one district). On average, there are 40 two-digit occupational categories per district.

Other covariates measure the demographic composition of the workers at a district two-digit occupational level. Based on the individual level data I calculate the share of men, young (below 25 years) and old (above 55 years) workers in a district-two digit occupational cell.

The distance from the Austrian border can be measured in several ways. I downloaded the distance of the district seats from Vienna and Graz (from the page rome-2rio.com). This contains not only the distance in kilometres but also in travelling time using different means of transport (car, train and bus). Vienna and Graz are the two main cities not far from the Hungarian border. I defined the distance from the Austrian border as the minimum distance from these two cities by car using travelling time. It can be defined as the average of these distances or simply using only one city distance but these are highly correlated measures and therefore it does not change the estimations significantly (see descriptive statistics in Tables 1 and 16). For a robustness check, I use different distance measures (see details in Appendix C).

4.2 Estimated equations

I estimate the following equations:

$$\ln(wage_{odt}) = \beta_0 + \beta_1 \ln\left(\widehat{tight_{odt}}\right) + \rho X_{odt} + \theta_t + \zeta_{od} + u_{odt}$$
(2)

Table 1Summary statistics for district two-digit occupationallevel cells in Hungary on the estimation sample (2009–2017).Source: HST, NES, rome2rio.com and own calculations

Variable	Mean	Median	Std. Dev	Min	Max
log (wage)	12.2	12.2	0.5	7.0	15.1
log(tightness)	0.36	0.047	0.7	0	6.11
share of men workers (%)	53.6	55.6	28.2	0.0	100.0
share of young workers (%)	5.4	4.2	6.0	0.0	100.0
share of old workers (%)	16.2	14.8	10.5	0.0	100.0
distance time by car*	130.7	140.0	33.2	53.0	179.0
population (thousand persons)*	76.9	36.8	210.8	13.1	1759.4

*Distance and population is measured at the district level

* refers to The "Distance time by car" and "Population (thousand persons" Note: The share of men, young and old workers can be 0 because these values are calculated from the employed in a district two-digit occupational cell not from the population. The estimation sample only contains those districts, which are closer than 180 min to the Austrian border

My main outcome variable is the private sector average wage in a given district- occupational cell. As tightness is endogenous in the wage equation I estimate the first stage as well.

The first stage is the following:

$$\ln (\text{tight}_{\text{odt}}) = \alpha_0 + \alpha_1 \text{after} 2010_t \times \text{dist}_d + \rho X_{\text{odt}} + \theta_t + \zeta_{\text{od}} + v_{\text{odt}}$$
(3)

where the variables are the following:

- *o* is the index for two-digit occupational category,
- *d* is the index for district,
- *t* is the year index,
- *wageodt* is the average wage in the private sector in district *d* occupational category *o* at time *t*,
- *tight_{odt}* is the tightness in district *d* occupational category *o* at time *t* (for calculation details see Appendix A.l).
- *dist_d*—distance from the Western border (in minutes by car),
- $after 2010_t = 1$ if year > 2010, 0 otherwise,
- *X_{odt}* other covariates: share of men employees, share of young employees (below 25 years), share of old employees (above 55 years) in a given district-occupational category cell,
- θ_t time fixed effect,
- ζ_{od} district two-digit occupational level fixed effect.

I also include time fixed effects, as wages rise steadily over time. Since the regulations on the unemployment benefit are the same across the country and they usually change yearly, time fixed effects also capture the effect of unemployment benefit, which is in Eq. (1).

Table 2 First stage of the main IV specification

	log(tightness)
Distance <i>x</i> after2010	-0.00296*** (0.000580)
Share of men workers	-0.00142*** (0.000256)
Share of young workers	0.00299*** (0.000816)
Share of old workers	0.000130 (0.000460)
Observations	22,258
Time horizon	2009–2017
District-occup. cat. FE	Yes
Year FE	Yes
Distance	< 180
F-stat	26.09
p-value	0.000

The dependent variable is the log tightness in a district two-digit occupational cell. The independent variable is the distance from the Austrian border and its interaction with the after2010 dummy. Other covariates are the share of men, young and old employees in a district two-digit occupational cell, year and district two-digit occupational category FEs. The sample contains those districts for which the minimum of the distance to Vienna and Graz is less than 180 min. Standard errors are clustered at the district level.

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

4.3 Main results

In the first stage equations, the coefficient of the *distance* x *after2010* variable is negative (see Table 2). This is intuitive as it means that the farther a district is from Austria, the lower the tightness was after the opening of the Austrian labour market.

The coefficient of tightness in the main specification means that if the tightness increases by 1 per cent, then wages grow by 0.23 per cent, controlling for demographic factors and district-occupational category and year FEs (see Table 3). Decomposing the change in predicted wages into the observed changes in these explanatory variables, the tightness contribution amounted to roughly one quarter of the total wage increase.⁶

4.4 OLS and reduced form

If tightness increases, wages also increase. But in the meantime (due to reverse causality) the higher wages imply lower tightness because more unemployed are willing to fill a job. This means that in the OLS estimation the parameter of tightness in the wage equation is downward-biased (Table 4). For the OLS I estimate Eq. 2 except for that tightness is not instrumented.

The reduced form is the following equation:

Table 3 Main IV specification

	log (wage)
Log(tightness)	0.233** (0.0968)
Share of men workers	0.00288*** (0.000267)
Share of young workers	-0.00567*** (0.000695)
Share of old workers	-0.00198*** (0.000649)
Observations	22,258
Time horizon	2009–2017
District-occup. cat. FE	Yes
Year FE	Yes
Distance	< 180
Time horizon	2009–2017

The dependent variable is the log private sector fte wage in a district two-digit occupational cell. The independent variable is the log tightness in a district-two digit occupational cell. Other covariates are the share of men, young and old employees in a district two-digit occupational cell, year and district two-digit occupational category FEs. The instrumental variable is the distance from the Austrian border and its interaction with the after2010 dummy. The sample contains those districts, for which the minimum of the distance to Vienna and Graz is less than 180 min. Standard errors are clustered at the district level. ***p < 0.01, **p < 0.05. *p < 0.1

$$ln(wage_{odt}) = \delta_0 + \delta_1 after 2010_t \times dist_d + \gamma X_{odt} + \theta_t + \zeta_{od} + u_{odt}$$
(4)

where the variables are the following:

- *o* is the index for two-digit occupational category,
- *d* is the index for district,
- *t* is the year index,
- *wageodt* is the average wage in the private sector in district *d* occupational category *o* at time *t*
- *tight*_{odt} is the tightness in district *d* occupational category *o*at time *t* (for calculation details see Appendix A.l).
- *dist_d*—distance from the Western border (in minutes by car),
- $after 2010_t = 1$ if year > 2010, 0 otherwise,
- *X_{odt}* other covariates: share of men, share of young (below 25 years), share of old employees (above 55 years) in a given district-occupational category cell,
- θ_t time fixed effect.
- ζ_{od} district two-digit occupational level fixed effect.

In the reduced form the *distance x after*2010 negatively affects wages (see Table 4). The parameter of interest means that, after the opening of the Austrian labour market, wages decline by 0.07 percentage for every additional 1 min of travelling time to Austria. Thus, if a district is 180 min farther from the Austrian border than another wages are 12 per cent lower there (controlling for demographic factors and district-occupational category and year FEs).

⁶ I calculated the annual change in the average predicted wage from the regression and decompose it into the change in observed factors, i.e. symbolically $\Delta \log(\widehat{wage}) = \sum_i \Delta \widehat{\beta}_i X_i$, where $x_i s$ are the explanatory variables. $\widehat{\beta}_i$ s are the estimated parameters. I calculated the ratio of $\Delta \log$ (tightness)/ $\Delta \log$ (wage) for every year and averaged across years.

	OLS log (wage)	Reduced form
	iog (wage,	log (wage)
Log(tightness)	-0.00122 (0.00311)	
distance x after2010		-0.000689*** (0.000180)
Share of men workers	0.00256*** (0.000204)	0.00255*** (0.000203)
Share of young workers	-0.00491*** (0.000650)	-0.00498*** (0.000657)
Share of old workers	-0.00191*** (0.000619)	-0.00195*** (0.000615)
Observations	22,258	22,258
R-squared	0.863	0.864
Time horizon	2009–2017	2009–2017
District—occupational category FE	Yes	Yes
Year FE	Yes	Yes
Distance	<180	< 180

In the OLS and the reduced form the dependent variable is the log private sector fte wage in a district-two digit occupational cell. Other covariates are the share of men, young and old employees in a district two-digit occupational cell, district two-digit occupational category and year FEs. In the OLS the independent variable is the log tightness in a district two-digit occupational cell. In the reduced form the independent variable is the distance from the Austrian border and its interaction with the after2010 dummy. The sample contains those districts for which the minimum of the distance to Vienna and Graz is less than 180 minutes. Standard errors are clustered at the district level

*** p<0.01. **p<0.05. *p<0.1

4.5 Robustness checks

Apart from the main specification I perform some robustness checks to examine the stability of the results.

First, I split the sample according to the one-digit occupational categories. In the case of white-collar occupations, there is only one category where the coefficient of tightness is significantly positive (Table 5). The magnitude is quite similar to the main specification. In other categories, the coefficients are positive but the standard errors are large. Among the five blue-collar categories four have significant coefficient (Table 6). The magnitude of the coefficients is also similar to the main specification. These results are not surprising since most Hungarians work in blue-collar occupations in Austria (see Fig. 9). Of course, we do not know what kind of work they had in Hungary. There is anecdotal evidence that some white-collar Hungarians work in bluecollar jobs in Austria but we have no hard data on this phenomenon. This could be the reason for the one significant parameter among the white-collar categories.

Second, I change the distance from the Austrian border. In the first case, I include those districts which are closer than 120 min, while in the second case I include

Table 5	Robustness	check for	white-collar	occupational	categories

	1	2	3	Λ
Occ. category	log(wage)	z log(wage)	o log(wage)	4 log(wage
Log(tightness)	0.138 (0.557)	0.0678 (0.147)	0.302** (0.136)	0.108 (0.0856)
Share of men workers	-0.00496*** (0.00149)	-0.000665 (0.000725)	0.00544*** (0.000555)	0.000623 (0.00115)
Share of young workers	-0.0151*** (0.00328)	-0.00314*** (0.00108)	-0.00309*** (0.000850)	-0.00157* (0.000896)
Share of old workers	-0.00279 (0.00172)	-0.00194** (0.000825)	-0.00154* (0.000820)	0.00200 (0.00126)
Observations	2257	4440	4645	1170
District—occ. cat. FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Time horizon	2009-2017			
Distance	< 180			
1st stage F-stat	7.26	6.71	14.6	16.16
p-value	0.009	0.0118	0.0003	0.0002

The dependent variable is the log private sector fte wage in a district two-digit occupational cell. The independent variable is the log tightness in a district two-digit occupational cell. Other covariates are the share of men, young and old employees in a district two-digit occupational cell, year and district two-digit occupational cells. The instrumental variable is the distance from the Austrian border and its interaction with the after2010 dummy. The sample contains those districts for which the minimum of the distance to Vienna and Graz is less than 180 min. Occupational categories: 1 Managers, 2 Professionals, 3 Technicians and associate professionals, 4 Office and management (customer services) occupations. Standard errors are clustered at the district level.

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

Table 4 The OLS and reduced form specification

Occ. category	5 log (wage)	6 log(wage)	7 log (wage)	8 log (wage)	9 log (wage)
Log(tightness)	0.152** (0.0690)	0.446 (0.275)	0.313** (0.149)	0.272** (0.107)	0.176*** (0.0630)
Share of men workers	0.00385*** (0.00141)	0.00394*** (0.000891)	0.00557*** (0.000572)	0.00370*** (0.000519)	-0.000254 (0.000863)
Share of young workers	-0.0149*** (0.00166)	0.000421 (0.00101)	-0.00733*** (0.00176)	-0.000377 (0.00264)	0.00562** (0.00226)
Share of old workers	-0.0169*** (0.00126)	0.000808 (0.000712)	0.000578 (0.00121)	0.00655*** (0.00210)	0.00253 (0.00217)
Observations	1300	1307	3434	2145	1560
Time horizon	2009–2017				
District—occ. cat. FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Distance	< 180				
1st stage F-stat	14.51	11.52	22.2	26.8	11.4
p-value	0.0003	0.0012	0	0	0.0012

Table 6	Robustness	check for	blue-collar	occupational	categories

The dependent variable is the log private sector fte wage in a district two-digit occupational cell. The independent variable is the log tightness in a district two-digit occupational cell. Other covariates are the share of men, young and old employees in a district two-digit occupational cell, year and district two-digit occupational cell of two-digit occupational cells. The instrumental variable is the distance from the Austrian border and its interaction with the after2010 dummy. The sample contains those districts, for which the minimum of the distance to Vienna and Graz is less than 180 min. Occupational categories: 5 Commercial and services occupations, 6 Agricultural and forestry occupations, 7 Industry and construction industry occupations, 8 Machine operators, assembly workers, drivers of vehicles, 9 Elementary occupations not requiring qualification. Standard errors are clustered at the district level.

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



Fig. 9 Hungarian workers' occupational categories in Austria, 2015. Source: Austrian Social Security Database. Other: civil servant, apprenticeship, marginal worker, freelance contract

those which are closer to the border than 240 min. In these cases, the point estimates are about half as large as in the main specification (Table 7). In the case of the 120 min specification the standard errors are larger because the number of observations decreased and close to the border the variance in the distance also decreased. This may also explain why the instrument is not too strong (the F-statistic is lower than 10).

The difference between average wages may be due to a change in the composition of workers. To filter out this effect, I recalculated the average wages from 2009 to 2017 using only those who were working in 2009. The coefficient of tightness is quite similar to the main specification (Table 8), and therefore composition effect can be ruled out.

Table 7 Rob	ustness c	check with	different	distances
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	(1) log (wage)	(2) log (wage)
Log(tightness)	0.105 (0.207)	0.143** (0.0672)
Share of men workers	0.00285*** (0.000474)	0.00286*** (0.000172)
Share of young workers	-0.00541*** (0.00132)	-0.00428*** (0.000469)
Share of old workers	-0.00411*** (0.00116)	-0.00117** (0.000471)
Observations	7485	40714
Distance	<120	< 240
Time horizon	2009–2017	
District—occ. cat. FE	Yes	Yes
Year FE	Yes	Yes
1st stage F-stat	2.71	31.53
p-value	0.1147	0.0000

The dependent variable is the log private sector fte wage in a district two-digit occupational cell. The independent variable is the log tightness in a district-two digit occupational cell. Other covariates are the share of men, young and old employees in a district two-digit occupational cell, year and district two-digit occupational cell, she distance from the Austrian border and its interaction with the after2010 dummy. The sample contains those districts for which the minimum of the distance to Vienna and Graz is less than 120 and 240 min respectively. Standard errors are clustered at the district level.

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

Since it is not specified in the database who works exactly where in Austria, I constructed a different distance measure, which does not include any destinations in Austria. As another robustness check, I calculated the distance between six border crossings with Austria and the district seats. I obtained very similar results as in the

Table 8Robustness check for those who worked in the privatesector in 2009

Log(tightness) 0.20)4** (0.0907)
Share of men workers 0.00)351*** (0.000234)
Share of young workers -0.0	00501*** (0.000786)
Share of old workers -0.0	000834 (0.000515)
Observations 220	18
Time horizon 200	9–2017
District—occ. cat. FE Yes	
Year FE Yes	
Distance <12	80
1st stage F-stat 28.3	34
p-value 0.00	000

The dependent variable is the log private sector fte wage in a district two-digit occupational cell. The independent variable is the log tightness in a district two-digit occupational cell. Other covariates are the share of men, young and old employees in a district two-digit occupational cell, year and district two-digit occupational cell, year and district two-digit occupational category FEs. The instrumental variable is the distance from the Austrian border and its interaction with the after2010 dummy. The sample contains those districts for which the minimum of the distance to Vienna and Graz is less than 180 min. The average wage in each year are calculated for those, who were employed in 2009 in the private sector. Standard errors are clustered at the district level.

****p<0.01, **p<0.05. *p<0.1

main specification (see Appendix C). Furthermore, I also constructed the database with wages and tightness also measured at the one-digit occupational level (see Appendix D). In both cases, the results do not change much.

I also calculated the effect using individual-level data. In this specification wages are measured at the individual level but tightness is only measured at the district two-digit occupational level. The estimated parameter is significant with the same magnitude as in the main specification (see Appendix E).

4.6 Robustness check using Slovakian data

It seems reasonable to check this IV setup in other countries. Slovakia joined the EU at the same time as Hungary, and thus the labour market opening affected the two countries at the same time. Moreover, it also has a common border with Austria and the distance magnitudes between Vienna and Slovakian towns are similar to the Hungarian counterparts (see Fig. 3).

There were similar economic patterns in the case of Slovakia as in Hungary. The financial crisis hit the Slovakian economy severely, with the country's GDP contracting by more than 5 per cent in 2009. The number of unemployed rose significantly in 2009, and the rate continued to increase until 2012. Since 2013 a considerable decline has been observed. The number of vacancies at the Central Office of Labour also decreased in

Table 9	Data used to construct district-occupational level
vacancy	for Slovakia

Geographic unit	With aggregated occupational category	With occupational category
District	2009–2011	2012–2017

2009. This was also true for the job advertisements on the largest Slovakian job search portal. After some stagnation, labour demand started increasing around 2013. The regional differences are notable in Slovakia as well. In the east and south-east parts of the country, the improvement in the labour market conditions was slower than in the west part of the country. The opening of the Austrian labour market affected the country in the same way as Hungary.

As in the Hungarian case I use annual data, for the same time span (2009–2017). Unfortunately, the district occupational-level data is not available for this whole period and accordingly I calculated it for the missing periods as follows.

Vacancy data are available at the district one-digit occupational level for Slovakia from 2012 (from the Central Office of Labour, Social Affairs and Family—ÚPS-VaR). For 2009–2011 vacancy data are available in a more aggregated form (Table 9). The data are available at a district level, but for occupational category 1–4 (the sum of occupational category 1 to 4), 5, 6–8 (the sum of occupational category 6 to 8) and 9. I calculated the average share of each one-digit occupational category in 1–4 and 6–8 between 2012 and 2017 for each district. Using these shares, I multiplied the number of vacancies in category 1–4 and 6–8 in each district between 2009 and 2011. This approach yields the vacancies at the district one-digit occupational level for the missing period.

In Slovakia the number of registered unemployed is available at the district one-digit occupational level (in the ÚPSVaR database). The occupation is defined based on the last occupation before the unemployment registration. This structure is available between 2013 and 2017 (Table 10). I calculated the average share of each occupation in each district based on the available data. I multiplied the number of unemployed in each district with these shares between 2009 and 2012. In this way, I obtained the number of unemployed in each district in each occupational cell for 2009–2012.

To calculate the district occupational-level average wage, I used the regional occupational-level average wage and the district average wage (source: Statistical Office of the Slovak Republic—SOSR). There are 8 regions in Slovakia and 79 districts. Each region consist of roughly 10 districts. The average wage at the one-digit occupational level is available for the regional level between

Table 10	Data use	d to cor	nstruct	district-oc	cupational	level
unemploy	ment for	Slovakia	1			

Geographic unit	Without occupational category	With occupational category
District	2009–2012	2013-2017

 Table 11
 Data used to construct district-occupational level

 wages for Slovakia
 Provide the state of the sta

Geographic unit	Without occupational category	With occupational category
District	2009–2017	
Region		2012-2017
Country		2009-2011

2012 and 2017 (Table 11). I calculated the ratio of each regional occupational-level wage to the country occupational level wage. The one-digit occupational-level country average wage is available from 2009. I multiplied the

country occupational-level wages in each category with the regional ratios. In this way, I calculated the average wage in each occupational category in each region between 2009 and 2011. In each region, I calculated the ratio of each category to the regional average wage in each year. With these ratios, I multiplied the district average wage in each year, thus obtaining the annual district occupational-level average wage.

Consequently, I have district one-digit level data for vacancy, unemployment and wages.

The share of men employees in each district—onedigit occupational cell is from the SOSR. The share of young and old employees in a district-occupational cell is missing in the Slovakian case. On the other hand, I can include district-occupational FEs. Due to the construction of the data I consider the Slovakian example as a robustness check rather than of a full analysis.

Figures 10 and 11 illustrates that district level tightness and wages have a strong correlation. Similarly to Hungary, wages are higher in the west of the country. The dynamics in tightness are also similar in both countries,



Fig. 10 Tightness in Slovakia at the district level, 2015. Source: own calculations based on ÚPSVaR



Fig. 11 Average wages in Slovakia at the district level, 2015. Source: SOSR



Fig. 12 Tightness before and after 2011 in the regions of Slovakia

 Table 12
 Summary statistics for district one-digit occupational cells in Slovakia on the estimation sample, 2009–2017. Source:

 SOSR, ÚPSVaR, rome2rio.com and own calculations

Variable	Mean	Median	Std. Dev	Min	Max
Log (wage)	6.7	6.6	0.4	5.7	8.1
Log(tightness)	1.6	1.2	1.4	0.0	8.2
Share of men workers	51.5	47.3	21.1	0	100
Distance from Vienna (min)*	120.3	126.5	38.7	52.0	178.0
Population (thousand per- sons)*	71.5	61.9	39.1	16.4	159.1

*The distance and the population is measured on district level

* refers to The "Distance time by car" and "Population (thousand persons"

i.e. after 2011 the increase in tightness was higher in regions, 7 which are closer to the border (see Fig. 12).

The distances of the district seats and Vienna are from the page rome2rio.com as in the case of Hungary. Descriptive statistics are in Table 12 for the estimation sample and in Table 17 for the whole country.

Figure 13 illustrates the validity of the IV in the case of Slovakia. In Austria, the highest percentage of Slovakian employees work along the border. This suggests that these workers commute from Slovakia to Austria (although there is no data on place of residence in the Austrian Social Security Database).

The estimated equations are the same as in the Hungarian case (see Eq. (2) and (3)) except for that everything

is measured at the one-digit occupational level and the share of young and old workers are missing.

The OLS and reduced form specifications are similar to the Hungarian results (Table 13). The OLS estimation is downward biased, as in the Hungarian case (see Table 4 and for the one-digit level Table 21). The parameter in the reduced form is also negative and significant as in the Hungarian case. The magnitude of the parameter is somewhat larger.

In the main IV specification the sign of the estimated coefficients are the same as in the Hungarian case (see Table 14). On the other hand, the point estimate is somewhat smaller, the coefficient is 0.18. This means that in the case of a 1 per cent increase in tightness the wage increases by 0.18 per cent. Decomposing the average predicted wage change the contribution of tightness is roughly half of the total wage change.

The 95% confidence interval in the Slovakian case is [0.08, 0.28], while in the Hungarian case it is [0.04, 0.42], The Hungarian confidence interval covers the Slovakian one, and thus we cannot say that the two parameters are significantly different from each other.

The parameter of interest in the first stage equations is negative and significant. This means that in the case of both countries, after the opening of the Austrian labour market the farther from the border the lower the tightness.

As the available Slovakian data are not as detailed as the Hungarian data, I cannot perform as many robustness checks as in the Hungarian case. I checked how sensitive the result is to the change in the distance from the Austrian border. The results show that the tightness parameter exhibits smaller changes if I modify

⁷ A region is a larger administrative unit in Slovakia. There are 8 regions in Slovakia, which correspond to NUTS 3 level local administrative units. A region contains 7–13 districts. It is more transparent to graph 8 lines instead of 79 that is why I graph regions instead of districts on Fig. 12.



Fig. 13 Proportion of Slovakian workers in Austria by municipality 2011–2015 Source: Schmieder (2019) p. 95. (Austrian Social Security Database)

the distance (Table 15). This result is different from the Hungarian estimates. On the other hand, in the case of both countries, one similarity is that the F-statistic is below 10 if only districts, which are closer than 120 min to the border are included. This results shows that the instrument is not strong enough if we select the closest districts because there is not enough variance.

The estimation for occupational categories is somewhat different than in the Hungarian case (see Appendix F). However, one should take into account that the Slovakian data are not so rich, and therefore the comparison must be interpreted with caution.

The results of the estimation exercise on the Slovakian data show that the effect of tightness on wages in general is similar to the Hungarian case. This suggests that tightness has a similar impact on one of the most

	Table 13	OLS and	reduced	form	for	Slovakia
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	OLS log(wage)	Reduced form log(wage)
Log(tightness)	0.0460*** (0.0126)	
Share of men workers	0.00259*** (0.000668)	0.00203*** (0.000532)
Distance x after2010		-0.00167*** (0.000535)
Observations	3393	3393
R-squared	0.907	0.908
Time horizon	2009-2017	2009-2017
Time FE	Yes	Yes
District—occ. cat. FE	Yes	Yes
Distance	< 180	< 180

The dependent variable is the district-one digit occupational level log private sector fte wage. The independent variable is the log tightness on district-one digit occupational level in the OLS case and the distance from the Austrian border and its interaction with the after2010 dummy in the reduced form. Other covariates are the share of men in district-occupational category, district-occupational category and year FEs. The sample contains those districts, for which the distance to Vienna is less than 180 min. Standard errors are clustered at district level.

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

important components of cost-push inflation in both countries.

5 Conclusions from a macroeconomic perspective

In this paper, I analysed the effect of tightness on wages in two Central European countries, using annual, district occupational-level data to have variation across space, occupations and time. For the identification, an instrumental variable method was applied, since tightness is endogenous in the wage equation. My IV variable was the interaction of the distance between a district and the Austrian border and a time dummy. The

Table 14 IV and 1st stage for Slovakia

	IV log(wage)	1st stage log(tightness)
Log(tightness)	0.181*** (0.0503)	
Share of men workers	0.00150** (0.000556)	0.00292 (0.00229)
Distance x after2010		-0.00920*** (0.00188)
Observations	3393	3393
Time horizon	2009-2017	2009-2017
Time FE	Yes	Yes
District—occ. cat. FE	Yes	Yes
Distance	< 180	< 180
F-stat		24.06
p-value		0.000

The dependent variable in the IV is the district-one digit occupational level log private sector fte wage. The independent variable is the log tightness on district-one digit occupational level. Other covariates are the share of men in district-occupational category, district-occupational category and year FEs. The instrumental variable is the distance from the Austrian border and its interaction with the after2010 dummy. The sample contains those districts, for which the distance to Vienna is less than 180 min. Standard errors are clustered at district level.

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

 Table 15
 Robustness check with different distance measures for
 Slovakia

Distance	<120 log (wage)	<240 log(wage)	
Log(tightness)	0.241*** (0.0806)	0.195*** (0.0431)	
Share of men workers	0.00211 (0.00178)	0.00183*** (0.000536)	
Observations	1530	4203	
Time horizon	2009-2017	2009-2017	
Time FE	Yes	Yes	
District—occ. cat. FE	Yes	Yes	
1st stage F-stat	9.18	27.42	
p-value	0.0072	0.0002	

The dependent variable is the district-one digit occupational level log private sector fte wage. The independent variable is the log tightness in district-one digit occupational level. Other covariates are the share of men in district-occupational category, district- occupational category and year FEs. The instrumental variable is the distance from the Austrian border and its interaction with the after2010 dummy. The sample contains those districts, for which the distance to Vienna is less than 120 and 240 min respectively. Standard errors are clustered at district level.

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

Austrian labour market was fully opened to the new member states in 2011. This induced a negative labour supply shock both in Hungary and Slovakia. Since commuting is only a viable option for those who live close to the western border, my main specification includes the districts which are close to the border. Accordingly, districts with similar development levels are contained in the sample. I concluded that tightness has a positive effect on wages in two Central European countries. In Hungary and Slovakia, this effect is significant and the coefficients are positive.

Some studies estimate or calibrate the tightness parameter in the wage equation; for example Shimer (2005) and Hagedorn and Manovskii (2008) calibrates the parameter in a full-scale macroeconomic model based on US data. Shimer (2005) finds that $\beta\gamma_0$ is 0.1534, while Hagedorn and Manovskii (2008) calibrated 0.03. Hoeck (2022) estimated a figure of 0.032 for Danish data. My estimate (0.2) is somewhat larger compared to the previous findings, which may be due to the structural differences in the labour markets in these countries.

This paper demonstrates that labour market tightness has an effect on wages. There are several macro policies, where wages play a crucial role. I briefly demonstrate with three examples how my results can be applied in policy work. For monetary policy, it is important to know how labour market tightness affects wages because wages are one of the most important cost-push inflation factors. Accordingly, my results can help to forecast inflation and conduct monetary policy in an inflation targeting framework.

Another important policy application is the planning of the state budget. Personal income tax constitutes a major part of the government's revenue, and accordingly wage dynamics are important in budget planning. A higher level of tightness suggests higher personal income tax revenue. If the government wants to reform the personal income tax the outlook for wage dynamics helps to assess the possible impact of policy changes.

In GDP forecasting, wages also play a crucial role. Wage dynamics are an important element of consumption forecasting, which is a key component of GDP. A reliable GDP forecast is an essential part of any kind of macro policy.

Appendix

See Table 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26

 Table 16
 Summary statistics for district two-digit occupational cells in Hungary, 2009–2017. Source: HST, NES, rome2rio.com and own calculations

Variable	Mean	Median	Std. Dev	Min	Max
Log (wage)	12.2	12.1	0.5	6.3	17.0
Log(tightness)	0.27	0.02	0.55	0.00	6.11
Share of men workers (%)	54.0	55.6	29.1	0.0	100.0
Share of young workers (%)	5.6	4.3	6.7	0.0	100.0
Share of old workers(%)	16.0	14.6	11.2	0.0	100.0
Distance time by car*	203.4	212.0	67.2	53.0	328.0
Population (thousand persons)*	56.6	34.8	133.5	8.4	1759.4

*The distance and the population is measured on district level

* refers to The "Distance time by car" and "Population (thousand persons" Note: The share of men, young and old can be 0 because these are calculated from the employed in a district two-digit occupational cell not from the population

 Table 17
 Summary statistics for district one-digit occupational cells in Slovakia, 2009–2017. Source: SOSR, ÚPSVaR, rome2rio.com and own calculations

Variable	Mean	Median	Std. Dev	Min	Max
Log (wage)	6.62	6.57	0.40	5.66	8.10
Log(tightness)	1.25	0.92	1.30	0.00	8.21
Share of men	50.8	47.1	21.8	0	100
Distance from Vienna (min)*	198	174	97	52	390
Population (thousand per- sons)*	68.3	62.7	36.4	12.5	169.4

*The distance and the population is measured on district level

* refers to The "Distance time by car" and "Population (thousand persons"

Table 18 Estimation with different IV measures

	(1) log(wage)	(2) log(wage)
Log(tightness)	0.239*** (0.0866)	0.197*** (0.0738)
Share of men workers	0.00289*** (0.000259)	0.00283*** (0.000249)
Share of young work- ers	-0.00569*** (0.000693)	-0.00556*** (0.000672)
Share of old workers	-0.00198*** (0.000649)	-0.00197*** (0.000643)
Observations	22258	22258
Time horizon	2009-2017	2009-2017
District—occ. cat. FE	Yes	Yes
Year FE	Yes	Yes
Distance	< 180	< 180
Instrument	Disctance in km	Distance in time

The dependent variable is the log private sector fte wage in a district two-digit occupational cell. The independent variable is the log tightness in a district two-digit occupational cell. Other covariates are the share of men, young and old employees in a district two-digit occupational cell, year and district two-digit occupational category FEs. The instrumental variable is the distance from the closest Austrian border-crossings and its interaction with the after2010 dummy. The sample contains those districts, for which the minimum of the distance to Vienna and Graz is less than 180 minutes (same sample as in Table 3). Standard errors are clustered at the district level

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

Table 19 Estimation with different IV measure, first stage

	(1) log(tightness)	(2) log(tightness)
Distance x after2010	-0.00155*** (0.000312)	-0.00299*** (0.000469)
Share of men workers	-0.00140*** (0.000255)	-0.00141*** (0.000255)
Share of young work- ers	0.00293*** (0.000806)	0.00298*** (0.000806)
Share of old workers	7.94e-05 (0.000460)	0.000126 (0.000467)
Observations	22258	22258
R-squared	0.663	0.665
Time horizon	2009-2017	2009–2017
District—occ. cat. FE	Yes	Yes
Year FE	Yes	Yes
Distance	< 180	<180
Туре	km	minutes
1st stage F-stat	24.56	40.54
p-value	0.0000	0.0000

The dependent variable is the log tightness in a district two-digit occupational cell. The independent variable is the distance from the closest Austrian border-crossings (in kilometres and in minutes as well) and its interaction with the after 2010 dummy. Other covariates are the share of men, young and old employees in a district two-digit occupational cell, year and district two-digit occupational category FEs. The sample contains those districts for which minimum of the distance to Vienna and Graz is less than 180 minutes. Standard errors are clustered at the district level

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

Table 20 Alternative specification: both wages and tightness are measured at the one-digit occupational level, IV and first stage

	(1) log (wage)	(2) log(tightness)
_og(tightness)	0.124** (0.0487)	
Distance <i>x</i> after2010		-0.00473*** (0.000980)
Share of men workers	0.00491*** (0.000461)	0.00285 (0.00271)
Share of young workers	-0.00556** (0.00237)	0.0402*** (0.00859)
Share of old workers	-5.86e-05 (0.00104)	-0.00470 (0.00689)
Observations	5,265	5,265
Time horizon	2009-2017	2009–2017
District—occ. cat. FE	Yes	Yes
Year FE	Yes	Yes
Distance	< 180	< 180
1st stage F-stat		23.27
o-value		0.0000

The dependent variable is the log private sector fte wage in a district one-digit occupational cell. The independent variable is the log tightness in a district one-digit occupational cell. Other covariates are the share of men, young and old employees in a district one-digit occupational cell, year and district onedigit occupational category FEs. The instrumental variable is the distance from the Austrian border and its interaction with the after 2010 dummy. The sample contains those districts, for which the minimum of the distance to Vienna and Graz is less than 180 minutes. Standard errors are clustered at the district level

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

	OLS log(wage)	Reduced form
	log(wage,	
Log(tightness)	-0.00219 (0.00239)	
distance x after2010		-0.000587*** (0.000153)
share of men workers	0.00532*** (0.000331)	0.00527*** (0.000312)
share of young workers	-3.55e-05 (0.000934)	-0.000571 (0.000898)
Share of old workers	-0.000224 (0.000575)	-0.000642 (0.000554)
Observations	5265	5265
Time horizon	2009–2017	2009–2017
District—occ. cat. FE	Yes	Yes
Year FE	Yes	Yes
Distance	< 180	< 180

Table 21 Alternative specification: both wages and tightness are measured at the one-digit occupational level, OLS and reduced form

In the OLS and the reduced form the dependent variable is the log private sector fte wage in a district-one digit occupational cell. Other covariates are the share of men, young and old employees in a district one-digit occupational cell, district one-digit occupational category and year FEs. In the OLS the independent variable is the log tightness in a district one-digit occupational cell. In the reduced form the independent variable is the distance from the Austrian border and its interaction with the after2010 dummy. The sample contains those districts for which the minimum of the distance to Vienna and Graz is less than 180 minutes. Standard errors are clustered at the district level

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

Table 22 Estimation with individual level data

	(1) log (wage)	(2) log (wage)
Log(tightness)	0.221* (0.118)	0.177** (0.0841)
Men	0.117*** (0.00702)	
Age	0.0268*** (0.000677)	
Age ²	-0.000286*** (7.80e-06)	
Observations	12201246	12201246
Time horizon	2009–2017	2009–2017
Individual FE	No	Yes
District—occ. cat. FE	Yes	No
Year FE	Yes	Yes
Distance	< 180	< 180

The dependent variable is the log wage of an individual who works in the private sector. The independent variable is the log tightness in a district-two digit occupational cell. Other covariates are a dummy for men, age and age square for the individual and year FEs. Column (1) contains district two-digit occupational category FEs, Column (2) contains individual level FEs. The sample contains those districts for which the minimum of the distance to Vienna and Graz is less than 180 minutes. Standard errors are clustered at the district level

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

	(1) log(tightness)	(2) log(tightness)
Distance x after2010	-0.00300*** (0.000984)	-0.00327*** (0.000761)
Men	0.00421*** (0.00149)	
Age	0.000327 (0.000314)	
Age ²	-6.06e-06* (3.59e-06)	
Observations	12201246	12201246
Time horizon	2009–2017	2009-2017
Individual FE	No	Yes
District—occ. cat. FE	Yes	No
Year FE	Yes	Yes
Distance	<180	< 180
1st stage F-stat	9.29	18.48
p-value	0.0031	0.0000

 Table 23
 Estimation with individual level data, first stage

The dependent variable is the log tightness (on district-two digit occupational level) of an individual who works in the private sector. The independent variable is the distance from the Austrian border and its interaction with the after2010 dummy. Other covariates are a dummy for men, age and age square for the individual and year FE. Column (1) contains district two-digit occupational category FEs, Column (2) contains individual level FEs. The sample contains those districts for which the minimum of the distance to Vienna and Graz is less than 180 minutes. Standard errors are clustered at the district level

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

Table 24 Robustness check for white-collar occupational categories for Slovakia

Occ. category	1	2	3	4
	log (wage)	log (wage)	log (wage)	log(wage
Log(tightness)	1.312 (1.340)	0.523** (0.225)	0.339*** (0.117)	0.236** (0.0903)
Share of men workers	-0.0126 (0.0227)	0.00507 (0.00317)	0.0119*** (0.00325)	0.00280 (0.00222)
Observations	378	378	378	378
District—occ. cat. FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Time horizon	2009-2017			
Distance	< 180			
1st stage F-stat	0.8	4.86	8.86	9.69
p-value	0.3771	0.0331	0.0049	0.0034

The dependent variable is the log private sector fte wage in a district one-digit occupational cell. The independent variable is the log tightness in a district one-digit occupational cell. Other covariates are the share of men in district-occupational category, district-occupational category and year FEs. The instrumental variable is the distance from the Austrian border and its interaction with the after2010 dummy. The sample contains those districts for which the minimum of the distance to Vienna is less than 180 minutes. Occupational categories: 1 Managers, 2 Professionals, 3 Technicians and associate professionals, 4 Office and management (customer services) occupations. Standard errors are clustered at the district level

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

Occ. category	5	6	7	8	9
2 1	log (wage)	log (wage)	log (wage)	log(wage)	log (wage)
Log(tightness)	0.0769* (0.0457)	-0.0814 (0.124)	0.123*** (0.0407)	0.0790*** (0.0262)	0.0462 (0.0291)
Share of men workers	0.00514*** (0.00142)	-2.45e-05 (0.000610)	0.00391*** (0.000754)	0.000669 (0.00104)	-0.00105 (0.00158)
Observations	378	369	378	378	378
Time horizon	2009-2017				
District—occ. cat. FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Distance	< 180				
1st stage F-stat	11.13	5.38	25.74	45.26	30.01
p-value	0.0018	0.0256	0.0000	0.0000	0.0000

 Table 25
 Robustness check for blue-collar occupational categories for Slovakia

The dependent variable is the log private sector fte wage in a district one-digit occupational cell. The independent variable is the log tightness in a district one-digit occupational cell. Other covariates are the share of men in district- occupational category, district-occupational category and year FEs. The instrumental variable is the distance from the Austrian border and its interaction with the after2010 dummy. The sample contains those districts for which the minimum of the distance to Vienna is less than 180 min. Occupational categories: 5 Commercial and services occupations, 6 Agricultural and forestry occupations, 7 Industry and construction industry occupations, 8 Machine operators, assembly workers, drivers of vehicles, 9 Elementary occupations not requiring qualification. Standard errors are clustered at the district level.

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

Table 26	Main IV specification with alternative tightne	ess
measure		

	log (wage)
Log(tightness)	0.344** (0.144)
Share of men workers	0.00269*** (0.000222)
Share of young workers	-0.00571*** (0.000698
Share of old workers	-0.00192*** (0.000633)
Observations	22258
Time horizon	2009–2017
District-occup. cat. FE	Yes
Year FE	Yes
Distance	< 180
Time horizon	2009–2017
1st stage F-stat	26.53
p-value	0.0000

The dependent variable is the log private sector fte wage in a district two-digit occupational cell. The independent variable is the log tightness in a district-two digit occupational cell (the occupational level vacancy is divided by the total number of unemployed in each district). Other covariates are the share of men, young and old employees in a district two-digit occupational cell, year and district two-digit occupational cell capacity of the district two-digit occupational cell stream of the distract two-digit occupational cell was and district two-digit occupational category FE. The instrumental variable is the distance from the Austrian border and its interaction with the after2011 dummy. The sample contains those districts, for which the minimum of the distance to Vienna and Graz is less than 180 min. Standard errors are clustered at the district level.

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

A Database description

The database of the Hungarian State Treasury (HST) contains the full population, who had at least one day of legal work between 1997 and 2017. The following variables are used in the study:

- district-level place of residence,
- the wage,
- type of employment (e.g. self-employed, entrepreneur, employee, public worker etc.),
- four-digit occupational code (FEOR),
- weekly hours worked.

A.I Calculation of occupational-level tightness

There are nine main categories ⁸ in the Hungarian Standard Classification of Occupations (FEOR):

- 1 Managers,
- 2 Professionals,
- 3 Technicians and associate professionals,
- 4 Office and management (customer services) occupations,
- 5 Commercial and services occupations,
- 6 Agricultural and forestry occupations,
- 7 Industry and construction industry occupations,
- 8 Machine operators, assembly workers, drivers of vehicles,
- 9 Elementary occupations not requiring qualification.

Based on the skill requirements for each occupational category (see Janák et al. (2011)) I constructed the twodigit occupational-level tightness in the following manner. In each category, the numerator is the number of two-digit occupational-level vacancies. The denominators are the following:

⁸ Apart from armed forces occupations.

- For categories 1–2: the number of unemployed with a bachelor's or master's degree,
- For category 3: the number of unemployed with a bachelor's or master's degree plus the number of unemployed with high school,
- For categories 4–8: the number of unemployed with high school or post-secondary vocational education, secondary education (at grammar schools, vocational schools, trade schools) or primary level of education,
- For category 9: the number of unemployed with a primary level of education or without any education.

B Additional descriptive statistics

B.1 For Hungary

The descriptive statistics for the whole country (Table 16) are slightly different than for the estimation sample (Table 1). In the case of wages the minimum is smaller for the whole country than the estimation sample because the less developed districts are not in the estimation sample. There are 5 outliers for the whole country in the case of wages, and accordingly the maximum is larger for the whole sample. In case of all variables the mean and median values are roughly the same for the estimation sample and for the whole country. The only major difference is in the distance from the Austrian border, which is simply due to the selection of the estimation sample.

B.2 For Slovakia

As in the Hungarian case the descriptive statistics for the whole country (Table 17) are slightly different than for the estimation sample (Table 12). The only major difference is in the distance from the Austrian border, which is simply due to the selection of the estimation sample. For all variables the mean and median values are very similar for the estimation sample and for the whole country.

C Different measure of the instrument

Since it is not known in my database who works exactly where in Austria, I constructed a different distance measure, which does not include any destinations in Austria. Instead I downloaded the distances between six border crossings (Hegyeshalom, Sopron, Kópháza, Kőszeg, Búcsú, Rábafüzes) and the district seats. I calculated the minimum of these distances both in driving time and distance in kilometres. I used these two measures as alternative IVs. The estimated coefficients are significant and quite similar to the original estimation (Table 18). The first stages are also similar to the original estimation (Table 19). This means that my results are robust to a different type of distance measure.

D Robustness check at the one-digit occupational level

In this section I estimate the following equation:

$$\ln(wage_{jt}) = \beta_0 + \beta_1 \ln\left(\widehat{tight_{jt}}\right) + \rho X_{jt} + \theta_t + \zeta_j + u_{it}$$
(5)

where

- *j* is the index for district one-digit occupational cells,
- *t* is the year index,
- wage_{jt} is the average wage in the private sector for district one-digit occupational cells,
- *tight_{jt}* is the tightness for district one-digit occupational cells,
- X_{jt} other covariates (share of men workers, share of young workers (below 25 years), share of old workers (above 55 years) in a given district-occupational category cell),
- θ_t time fixed effect,
- ζ_{od} district two-digit occupational level fixed effect.

The only difference between the main specification (Eq. 2) and Eq. 5 is that in Eq. 5 both wages and tightness are measured at the district one-digit occupational level. The first stage equation is the same as in the main specification.

The parameter of interest is lower than the original estimation but the confidence interval of the main specification [0.04, 0.42] almost contains the confidence interval of this specification [0.03, 0.22].

E Robustness check with individual level data

In this section I examine whether the results change if I use individual level data. To do this, I use the raw data from which I calculated the two-digit level wages and the demographic variables. Tightness cannot be measured at the individual level, only for the district two-digit occupational category. Other variables are observed at the individual level. I estimate the following equation:

$$\ln(wage_{iodt}) = \beta_0 + \beta_1 \ln(\widehat{tight_{odt}}) + \beta_2 men_i + \beta_3 age_i + \beta_4 age_i^2 + \theta_t + \zeta_{od} + u_{iodt}$$
(6)

where.

- *i* is the index for individual,
- *o* is the index for two-digit occupational category,
- *d* is the index for district,
- *t* is the year index,
- *wage_{iodt}* is the wage for individual *i* in district *d* in occupational category *o* at time t,
- *tight_{odt}* is the tightuess in district *d* occupational category *o* time *t*,
- *men*_t is a dummy for men.
- *age*_i is the age of the individual,

- age_i^2 is the age square of the individual,
- θ_t time fixed effect.
- ζ_{od} district two-digit occupational level fixed effect.

I estimate the following first stage for this IV:

$$\ln (\text{tight}_{\text{odt}}) = \alpha_0 + \alpha_1 \text{after} 2010_t \times \text{dist}_d + \beta_2 \text{men}_i + \beta_3 \text{age}_i + \beta_4 \text{age}_i^2$$
(7)
+ $\theta_t + \zeta_d + v_{\text{odt}}$

If I include individual level FEs, the age and gender variables will automatically drop out both in the first and second stage as well.

The parameter of the log (tightness) is positive and significant (Table 22) in both estimations. The specification with the individual FEs has a slightly lower parameter estimate. The point estimate is probably lower because by using individual FEs I control for unobserved individual level characteristics. The magnitude of the parameter of interest is very similar to the original estimation. The 95% confidence interval is [0.04, 0.42] in the main specification, while it is [0.01, 0.34] in the individual FEs specification. The first stage parameters are quite similar in the two individual specification (see Table 23).

The estimation with individual level FE address that potential threat to IV validity, where a productivity shock is correlated with the distance from the Austrian border since the individual-level FE absorb most of the firm level shocks as well. Without controlling for these type of shocks the estimation would be upward-biased in the case of a positive productivity shock.

F Robustness check with occupational categories for Slovakian data

In this exercise, I split the sample according to the occupational categories. This specification is also different than in the Hungarian case, since everything is measure at the one-digit occupational level not at the two-digit level and some controls are missing. Furthermore, the tightness is calculated differently. In the Hungarian case the denominator is based on education, while in Slovakia the previous occupation is used. The results are more stable in the case of the blue-collar workers (Table 25) than for the white-collar workers (Table 24). Furthermore, the F-statistics are lower than 10 in case of white-collar workers, while there are blue-collar occupations, where it is well above 10. This suggests that most of the Slovakian workers worked previously in blue-collar occupations.

G Alternative specification with different measure of tightness

The tightness measure is derived from the number of vacancies within a two-digit occupation and the number of unemployed workers with a specific education level (e.g., high-skilled occupations are associated with higher education). This assumption relies on the idea that workers do not target vacancies below their educational attainment. One can argue that this assumptions does not hold in all cases. To address this concern I recalculated tightness by dividing by the total number of unemployed in every category. This does not restrict the educational level of the unemployed in the tightness measure. The regression results are similar to the original estimation (Table 26).

Comparing the results with the original estimation the parameter of interest is higher (0.23 vs. 0.34) but there is a large intersection of the two 95% confidence intervals ([0.04, 0.42] vs. [0.06, 0.62].

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Availability of data and materials

Due to the size and sensitivity of the data, access to it is provided exclusively for academic purposes by the Magyar Nemzeti Bank (Central Bank of Hungary). The data can be analysed only on the premises of the the Magyar Nemzeti Bank on reasonable request. The codes are available from the author upon request.

Declarations

Competing interests

The author declares that he has no competing interests.

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