Web Appendix

The Wage Response to Shocks: The Role of Inter-Occupational Labour Adjustment

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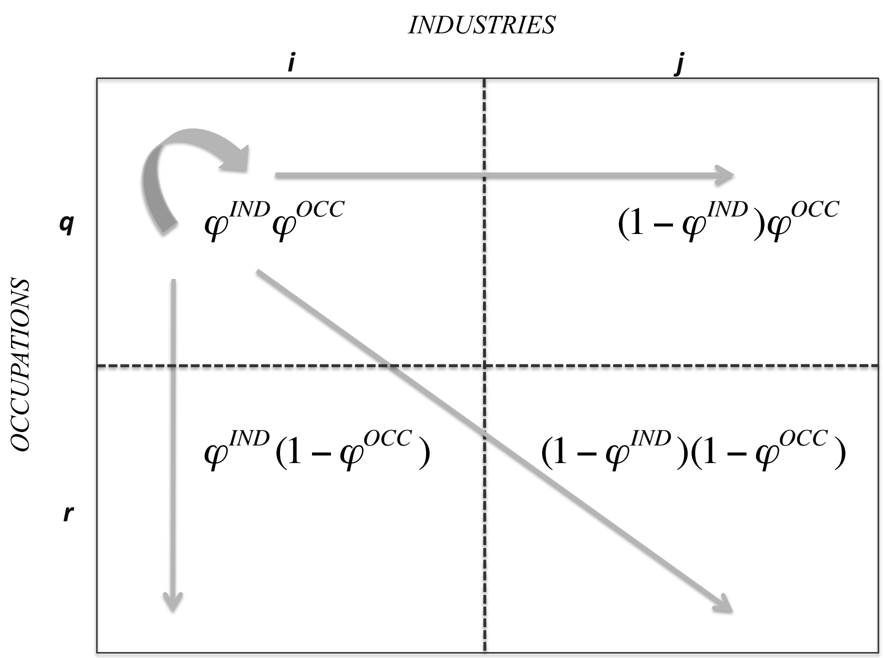
A Mobility illustration in a two-by-two occupation-industry model

Figure 1 illustrates mobility in a two-by-two occupation-industry model. Let i and j denote industry subscripts and q and r be occupation subscripts. $\varphi^{IND}\varphi^{OCC}$ captures the importance of worker immobility outside an occupation-industry cell. Mobility within occupation across industries is represented by the horizontal arrow and captured by $\varphi^{IND}\varphi^{OCC}$. The vertical arrow shows mobility within industry across occupations. This type of mobility is captured by $\varphi^{IND}(1-\varphi^{OCC})$. The importance of mobility across the entire industry-occupation matrix is captured by $(1-\varphi^{IND})(1-\varphi^{OCC})$ and represented by the diagonal arrow.

Figure 1: Mobility illustration in a two-by-two occupation-industry model.



B Stylized facts: worker mobility

Figure 2 and Table 1 present evidence of inter-industry and inter-occupational worker mobility. Evidence is constructed on the basis of employed individuals who can be traced over two consecutive years. Inter-industry mobility is defined as the fraction of currently employed individuals who report a current industry different from the industry reported one year earlier. Inter-occupational mobility is defined equivalently.

Figure 2 shows the evolution of workers' mobility across industries within a particular occupation, across occupations within a particular industry and across *both* industries and occupations, as a share of employed workers. Table 1 presents the associated summary statistics. On average, 8.1% of workers move across industries and/or occupations from one year to the other. 2.9% of workers move across industries within a particular occupation, 2.5% move across occupations within a particular industry and 2.7% move across both industries and occupations. Inter-industry and inter-occupational worker mobility are on average 5.6% and 5.2%, respectively.

Figure 2: Evolution of worker mobility across industries within occupation, across occupations within industry and across both industries and occupations as a share of West-German employed workers over the period 1977-2001.

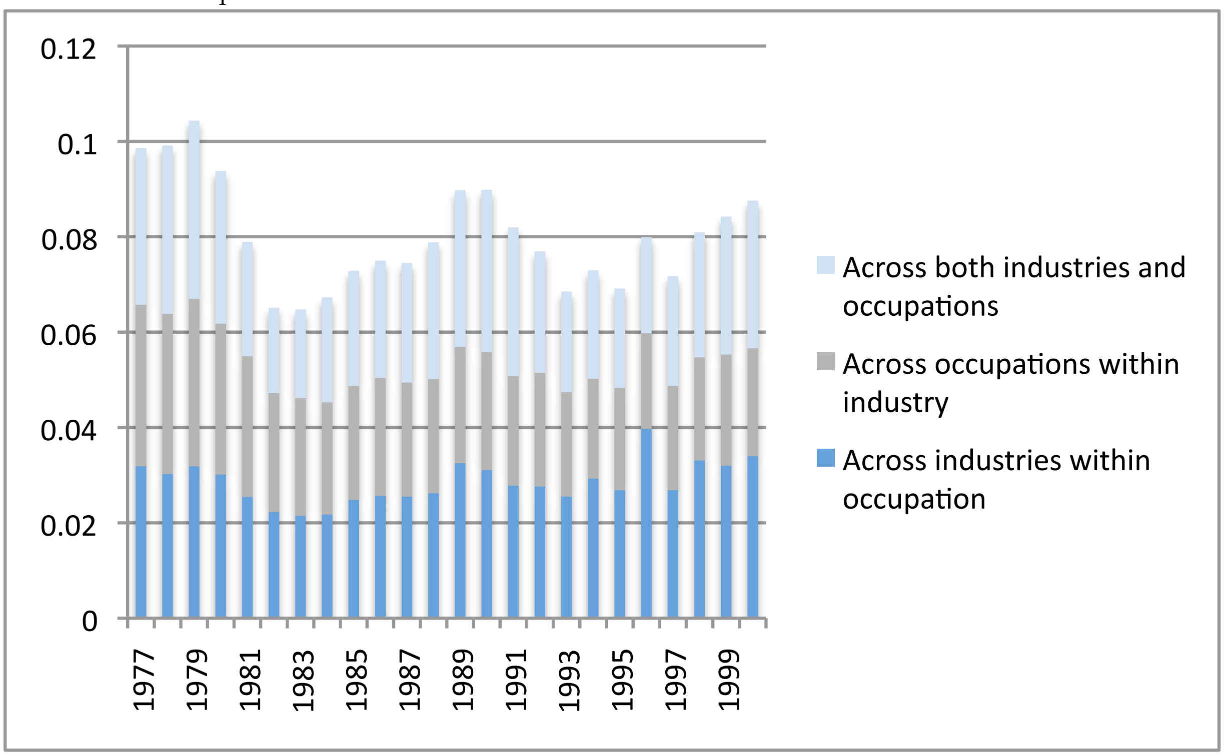


Table 1: Summary statistics (across years and cities): cross-industry and cross-occupational worker moves as a share of Western-German employed workers over the period 1977-2001.

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**
Share of employed workers who move:				
Across industries within occupation	0.029	0.004	0.022	0.040
Across occupations within industry	0.025	0.004	0.020	0.035
Across both industries and occupations	0.027	0.006	0.018	0.037
Mobility distribution:				
Across industries within occupation	0.356	0.042	0.305	0.497
Across occupations within industry	0.314	0.038	0.251	0.383
Across both industries and occupations	0.330	0.032	0.252	0.380

C Deriving the wage equation

This section discusses how equation (11) can be derived from equation (10) in the manuscript. The model implies the following wage equation (equation 10 in the manuscript)

$$\begin{aligned} w_{qic} &= \gamma_{1c}\lambda_{qic} + \gamma_{2c}\Big[(1-\varphi^{IND})\varphi^{OCC}\sum_{j}^{I}\eta_{jc,q}w_{qjc} \\ &+ \varphi^{IND}(1-\varphi^{OCC})\sum_{r}^{Q}\eta_{rc,i}w_{ric} + (1-\varphi^{IND})(1-\varphi^{OCC})\sum_{j,r}^{I\cdot Q}\eta_{rjc}w_{rjc}\Big], \end{aligned} \tag{1}$$

where $\lambda_{qic} = p_i\theta_{qic}\frac{Y_{ic}}{N_{qic}}$ and the γ's are functions of the employment rate.[1] Due to the strategic complementarity of occupation-industry-city wages, the parameters $\gamma_{2c}(1-\varphi^{IND})\varphi^{OCC}$, $\gamma_{2c}\varphi^{IND}(1-\varphi^{OCC})$ and $\gamma_{2c}(1-\varphi^{IND})(1-\varphi^{OCC})$ only capture partial spillover effects of a change in within-occupation, within-industry or within-city employment, respectively. These partial effects depend

[1] In particular,

$$\begin{aligned} \gamma_{1c} &= \frac{(\rho+\delta+\psi_c\varphi^{IND}\varphi^{OCC})}{[(\rho+\delta+\psi_c\varphi^{IND}\varphi^{OCC})+\kappa(\rho+\delta+\phi_c)]} \\ \gamma_{2c} &= \frac{(\rho+\delta+\phi_c)\kappa}{[(\rho+\delta+\psi_c\varphi^{IND}\varphi^{OCC})+\kappa(\rho+\delta+\phi_c)]}\frac{\psi_c}{(\rho+\delta+\psi_c)}, \end{aligned}$$

where ϕ_c and ψ_c are functions of the employment rate.

on city-specific employment rates (through γ_{2c}), which are themselves determined endogenously. In order to obtain the total spillover effects, the paper first solves equation (1) for wages. The paper then uses a first-order log-linear approximation to explicate the relationship between occupation-industry-city wages and the employment rate. Solving equation (1) for wages, one obtains

$$\begin{aligned} w_{qic} &= \gamma_{c1}\lambda_{qic} + \frac{\gamma_{1c}\gamma_{2c}}{1-\gamma_{2c}(1-\varphi^{IND}\varphi^{OCC})}\Bigg[(1-\varphi^{IND})\varphi^{OCC}\sum_{j}^{I}\eta_{jc,q}\lambda_{qjc} \\ &+ \varphi^{IND}(1-\varphi^{OCC})\sum_{r}^{Q}\eta_{rc,i}\lambda_{ric} + (1-\varphi^{IND})(1-\varphi^{OCC})\sum_{j,r}^{I\cdot Q}\eta_{rjc}\lambda_{rjc}\Bigg]. \qquad (2) \end{aligned}$$

In order to explicitly express the employment rate, the paper takes a log-linear approximation around the point where cities have an identical structure of employment. This occurs when the technology parameter θ_{qic} and the productivity shifter A_{ic} are city-invariant, i.e. $\theta_{qic} = \theta_{qi}$ and $A_{ic} = A_i$ (which implies $\eta_{ic,q} = \eta_{i,q}$, $\eta_{qc,i} = \eta_{q,i}$, $\eta_{qic} = \eta_{qi}$ and $ER_c = ER$). Define $\hat{\theta}_{qic} = \theta_{qic} - \theta_{qi}$, the occupation-industry-specific relative advantage component in the technology for city c, such that $\sum_c \hat{\theta}_{qic} = 0$. Similarly, define $\hat{A}_{ic} = A_{ic} - A_i$, the industry-specific relative advantage component in the productivity for city c, such that $\sum_c \hat{A}_{ic} = 0$. By definition, the structure of employment across industries and occupations is identical across cities (i.e. $\theta_{qic} = \theta_{qi}$ and $A_{ic} = A_i$) when the relative advantage components $\hat{\theta}_{qic}$ and $\hat{A}_{ic}$ are zero. Approximating equation (2) around the points where $\hat{\theta}_{qic} = 0$, $\hat{A}_{ic} = 0$, and $\eta_{ic,q} = \eta_{i,q}$, $\eta_{qc,i} = \eta_{q,i}$, $\eta_{qic} = \eta_{qi}$, $ER_c = ER$, one obtains

$$\begin{aligned} w_{qic} &= \gamma_1\lambda_{qi} - f_{qi}ER + f_{qi}ER_c + \frac{\gamma_1\gamma_2}{1-\gamma_2(1-\varphi^{IND}\varphi^{OCC})}\Bigg[(1-\varphi^{IND})\varphi^{OCC}\sum_{j}^{I}\eta_{jc,q}\lambda_{qj} \\ &+ \varphi^{IND}(1-\varphi^{OCC})\sum_{r}^{Q}\eta_{rc,i}\lambda_{ri} + (1-\varphi^{IND})(1-\varphi^{OCC})\sum_{j,r}^{I\cdot Q}\eta_{rjc}\lambda_{rj}\Bigg] + \xi_{qic}, \qquad (3) \end{aligned}$$

where the terms λ_{qi}, ER, γ_1 and γ_2 are λ_{qic}, ER_c, γ_{1c} and γ_{2c} evaluated at $\hat{\theta}_{qic} = 0$ and $\hat{A}_{ic} = 0$, respectively. The occupation-industry-specific term f_{qi} is obtained from the linear approximation and is a function of the following set of parameters: γ_1, γ_2, φ^{IND}, φ^{OCC} and λ_{qi}. The term ξ_{qic} is obtained from the linear approximation as well and corresponds to the error term in the empirical section. In particular, ξ_{qic} depends on the relative advantage components $\hat{\theta}_{qic}$ and $\hat{A}_{ic}$, i.e.

$$\begin{aligned}
\xi_{qic} &= \gamma_1 \left(g_{qi} \hat{\theta}_{qic} + h_{qi} \hat{A}_{ic} \right) \\
&+ \frac{\gamma_1 \gamma_2}{1 - \gamma_2 (1 - \varphi^{IND} \varphi^{OCC})} \Bigg[(1 - \varphi^{IND}) \varphi^{OCC} \sum_{j}^{I} \eta_{j,q} \left(g_{qj} \hat{\theta}_{qjc} + h_{qj} \hat{A}_{jc} \right) \\
&+ \varphi^{IND} (1 - \varphi^{OCC}) \sum_{r}^{Q} \eta_{r,i} \left(g_{ri} \hat{\theta}_{ric} + h_{ri} \hat{A}_{ic} \right) \\
&+ (1 - \varphi^{IND})(1 - \varphi^{OCC}) \sum_{j,r}^{I \cdot Q} \eta_{rj} \left(g_{rj} \hat{\theta}_{rjc} + h_{rj} \hat{A}_{jc} \right) \Bigg], \qquad (4)
\end{aligned}$$

where $\eta_{r,i}$, $\eta_{j,q}$ and η_{rj} are respectively $\eta_{rc,i}$, $\eta_{jc,q}$ and η_{rjc} evaluated at $\hat{\theta}_{qic} = 0$ and $\hat{A}_{ic} = 0$. The occupation-industry-specific terms g_{qi} and h_{qi} are obtained from the linear approximation and are functions of the parameters γ_1, γ_2, φ^{IND}, φ^{OCC} and λ_{qi}.

The last step to obtain equation (11) in the manuscript consists in expressing λ_{qi} as a function of the national occupation-industry wage premia. To do so, note that w_{qic} approximated around the point where $\hat{\theta}_{qic} = 0$, $\hat{A}_{ic} = 0$, and $\eta_{ic,q} = \eta_{i,q}$, $\eta_{qc,i} = \eta_{q,i}$, $\eta_{qic} = \eta_{qi}$ satisfies:

$$\begin{aligned}
&(w_{qic} - w_{1ic}) - (w_{q1c} - w_{11c}) \\
&= \gamma_1 \left[(\lambda_{qi} - \lambda_{1i}) - (\lambda_{q1} - \lambda_{11}) \right] \\
&+ \gamma_1 \left[(\xi_{qic} - \xi_{1i}) - (\xi_{q1} - \xi_{11}) \right] \\
&+ \gamma_1 \left[\left(f_{qi} \left[\hat{\theta}_{qic} + \hat{A}_{qic} \right] - f_{1i} \left[\hat{\theta}_{1ic} + \hat{A}_{1ic} \right] \right) - \left(f_{q1} \left[\hat{\theta}_{q1c} + \hat{A}_{q1c} \right] - f_{11} \left[\hat{\theta}_{11c} + \hat{A}_{11c} \right] \right) \right],
\end{aligned}$$

such that

$$\sum_{c}^{C} (w_{qic} - w_{1ic}) - (w_{q1c} - w_{11c}) = \gamma_1 \left[(\lambda_{qi} - \lambda_{1i}) - (\lambda_{q1} - \lambda_{11}) \right]. \qquad (5)$$

Define $\nu_{qi} = (w_{qi} - w_{11})$, the national occupation-industry wage premium relative some numeraire occupation and industry and let w_{qi} be the national occupation-industry average wage. One can then use equation (5) to obtain

$$\nu_{qi} = \gamma_1 \left(\lambda_{qi} - \lambda_{11} \right). \qquad (6)$$

Equation (6) suggests that the national occupation-industry wage premium is positively related to both the price of the intermediate good i and the marginal product of type-q labour in industry i.

Substituting (6) into (3) and adding the time subscript, the wage equation can be rewritten as

$$\begin{aligned} w_{qic\tau} &= \frac{\gamma_1\gamma_2(1-\varphi^{IND}\varphi^{OCC})}{1-\gamma_2(1-\varphi^{IND}\varphi^{OCC})}\lambda_{11\tau} + \gamma_1\lambda_{qi\tau} + f_{qi}ER_{c\tau} \\ &+ \frac{\gamma_2}{1-\gamma_2(1-\varphi^{IND}\varphi^{OCC})}\Bigg[(1-\varphi^{IND})\varphi^{OCC}\sum_{j}^{I}\eta_{jc\tau,q}\nu_{qj\tau} + \varphi^{IND}(1-\varphi^{OCC})\sum_{r}^{Q}\eta_{rc\tau,i}\nu_{ri\tau} \\ &+ (1-\varphi^{IND})(1-\varphi^{OCC})\sum_{j,r}^{I\cdot Q}\eta_{rjc\tau}\nu_{rj\tau}\Bigg] + \xi_{qic\tau}. \end{aligned} \tag{7}$$

Equation 11 in the manuscript is obtained by taking the first-difference with respect to time. Letting Δ denote a first difference, equation (7) becomes

$$\Delta w_{qic\tau} = \Delta d_{qi\tau} + \beta_1\Delta R^{IND}_{qc\tau} + \beta_2\Delta R^{OCC}_{ic\tau} + \beta_3\Delta R^{CITY}_{c\tau} + f_{qi}\Delta ER_{c\tau} + \Delta\xi_{qic\tau}, \tag{8}$$

where $f_{qi} > 0$ and

$$\begin{aligned} d_{qi\tau} &= \frac{\gamma_1\gamma_2(1-\varphi^{IND}\varphi^{OCC})}{1-\gamma_2(1-\varphi^{IND}\varphi^{OCC})}\lambda_{11\tau} + \gamma_1\lambda_{qi\tau} \\ R^{IND}_{qc\tau} &= \sum_{j}^{I}\eta_{jc\tau,q}\nu_{qj\tau} \\ R^{OCC}_{ic\tau} &= \sum_{r}^{Q}\eta_{rc\tau,i}\nu_{ri\tau} \\ R^{CITY}_{c\tau} &= \sum_{j,r}^{I\cdot Q}\eta_{rjc\tau}\nu_{rj\tau} \end{aligned}$$

and

$$\begin{aligned} \beta_1 &= \frac{\gamma_2}{1-\gamma_2(1-\varphi^{IND}\varphi^{OCC})}(1-\varphi^{IND})\varphi^{OCC} \geq 0 \\ \beta_2 &= \frac{\gamma_2}{1-\gamma_2(1-\varphi^{IND}\varphi^{OCC})}\varphi^{IND}(1-\varphi^{OCC}) \geq 0 \\ \beta_3 &= \frac{\gamma_2}{1-\gamma_2(1-\varphi^{IND}\varphi^{OCC})}(1-\varphi^{IND})(1-\varphi^{OCC}) \geq 0. \end{aligned}$$

D Implications of worker mobility across cities

Worker mobility across cities can be modelled as either random or directed search across cities. In what follows, the paper first extends the model to allow for random search across cities. This extension modifies the value of being unemployed to a worker. Assume that with probability $(1-\Gamma)$ an unemployed worker gets a random job draw from his or her city, while with probability Γ he or she gets a random job draw from *any* city. Letting $U^{u'}_{qic\tau}$ be the extended version of $U^{u}_{qic\tau}$ under random search, ones obtains

$$\begin{aligned} \rho U^{u'}_{qic\tau} &= (1-\Gamma)U^{u}_{qic\tau} + \Gamma\Big[\varphi^{IND}\varphi^{OCC}\underbrace{\sum_{c}^{C}\frac{N_{qic}}{N_{qi}}U^{e}_{qic\tau}}_{qi\tau\text{-specific term}} + (1-\varphi^{IND})\varphi^{OCC}\underbrace{\sum_{c}^{C}\sum_{j}^{I}\frac{N_{qjc\tau}}{N_{j\tau}}U^{e}_{qjc\tau}}_{q\tau\text{-specific term}} \\ &+ \varphi^{IND}(1-\varphi^{OCC})\underbrace{\sum_{c}^{C}\sum_{r}^{Q}\frac{N_{ric\tau}}{N_{r\tau}}U^{e}_{ric\tau}}_{i\tau\text{-specific term}} + (1-\varphi^{IND})(1-\varphi^{OCC})\underbrace{\sum_{c}^{C}\sum_{j,r}^{I\cdot Q}\frac{N_{rjc\tau}}{N\tau}U^{e}_{rjc}}_{\tau\text{-specific term}} - U^{u'}_{qic}\Big], \qquad (9) \end{aligned}$$

where $N_{qi\tau}$, $N_{q\tau}$ and $N_{i\tau}$ denote occupation-industry, occupation and industry national employment, respectively, and where N_{τ} denotes the national employment at time τ. Equation (9) suggests that allowing for random search across cities implies adding four terms to the wage equation: a $qi\tau$-specific, a $q\tau$-specific, a $i\tau$-specific and a time effect. Since these terms do not vary across cities and given that the baseline equation includes occupation-industry time-varying dummies, this extension has no impact on the estimates.

Directed search across cities can be modelled as follows. Assume that with probability $(1-\Lambda)$, an unemployed worker cannot move across cities. With probability Λ he or she has the option to move to another city and chooses the city, indexed by c', that maximizes his or her value of finding a job relative to being unemployed. Let $U^{u*}_{qic\tau}$ be the extended version of $U^{u}_{qic\tau}$ under directed search. The discounted value of being unemployed is given by

$$\rho U^{u*}_{qic\tau} = (1-\Lambda)U^{u}_{qic\tau} + \Lambda \max_{c'}\left[\underbrace{\sum_{j,r}^{I\cdot Q}\eta_{ric'\tau}U^{u}_{qic'\tau}}_{c'\tau\text{-specific term}} - U^{u*}_{qic\tau}\right].$$

Thus, allowing for directed search across cities implies adding a time-varying term to the wage equation. This has no incidence on the estimated coefficients since this term is captured by time fixed effects in the baseline specification.

E Inconsistency of OLS

This section shows why OLS leads to inconsistent estimates of β_1-β_3 and of the coefficient on the employment rate. In what follows, the paper focuses on the city composition index. Proofs for the other composition indices and for the employment rate are completely symmetric.

Consistency of OLS requires that

$$\lim_{I,Q,C\to\infty} \frac{1}{I}\frac{1}{Q}\frac{1}{C}\sum_{i}^{I}\sum_{q}^{Q}\sum_{c}^{C}\Delta R_{c\tau}^{CITY}\Delta\xi_{qic\tau} = 0, \tag{10}$$

where the city composition index can be decomposed in a "between" and a "within" component

$$\Delta R_{c\tau}^{CITY} = \underbrace{\sum_{j,r}^{I\cdot Q}\nu_{rj(\tau-1)}\Delta\eta_{rjc\tau}}_{\text{Between component}} + \underbrace{\sum_{j,r}^{I\cdot Q}\eta_{rjc\tau}\Delta\nu_{rj\tau}}_{\text{Within component}}, \tag{11}$$

and where the error term is given by

$$\begin{aligned}
\xi_{qic\tau} &= \gamma_1\left(g_{qi}\hat{\theta}_{qic\tau} + h_{qi}\hat{A}_{ic\tau}\right) \\
&+ \frac{\gamma_1\gamma_2}{1-\gamma_2(1-\varphi^{IND}\varphi^{OCC})}\Bigg[(1-\varphi^{IND})\varphi^{OCC}\sum_{j}^{I}\eta_{j,q}\left(g_{qj}\hat{\theta}_{qjc\tau} + h_{qj}\hat{A}_{jc\tau}\right) \\
&+ \varphi^{IND}(1-\varphi^{OCC})\sum_{r}^{Q}\eta_{r,i}\left(g_{ri}\hat{\theta}_{ric\tau} + h_{ri}\hat{A}_{ic\tau}\right) \\
&+ (1-\varphi^{IND})(1-\varphi^{OCC})\sum_{j,r}^{I\cdot Q}\eta_{rj}\left(g_{rj}\hat{\theta}_{rjc\tau} + h_{rj}\hat{A}_{jc\tau}\right)\Bigg].
\end{aligned} \tag{12}$$

Substituting equation (11) into (10), the consistency condition can be rewritten as

$$\begin{aligned}
\lim_{I,Q,C\to\infty} \frac{1}{I}\frac{1}{Q}\frac{1}{C}\Bigg[&\sum_{j}^{I}\sum_{r}^{Q}\nu_{rj(\tau-1)}\sum_{c}^{C}\Delta\eta_{rjc\tau}\sum_{i}^{I}\sum_{q}^{Q}\Delta\xi_{qic\tau} \\
&+\sum_{j}^{I}\sum_{r}^{Q}\Delta\nu_{rj\tau}\sum_{c}^{C}\eta_{rjc\tau}\sum_{i}\sum_{q}\Delta\xi_{qic\tau}\Bigg] = 0,
\end{aligned}$$

which is equivalent to requiring that the following two conditions be satisfied

$$\lim_{I,Q,C\to\infty} \frac{1}{I}\frac{1}{Q}\frac{1}{C}\sum_{c}^{C}\left[\Delta\eta_{rjc\tau}\sum_{i}^{I}\sum_{q}^{Q}\Delta\xi_{qic\tau}\right] = 0 \tag{13}$$

and

$$\lim_{I,Q,C\to\infty} \frac{1}{I}\frac{1}{Q}\frac{1}{C}\sum_{c}^{C}\left[\eta_{rjc\tau}\sum_{i}^{I}\sum_{q}^{Q}\Delta\xi_{qic\tau}\right] = 0. \tag{14}$$

However, these two conditions cannot be satisfied as the employment shares are correlated with the error term. This can be seen directly by noting that $\eta_{qic\tau}$, approximated around the point where $\hat{\theta}_{qic\tau} = 0$ and $\hat{A}_{ic\tau} = 0$, is given by

$$\begin{aligned}
\eta_{qic\tau} = \frac{1}{IQ} \quad &+ \quad \pi_1\left[g_{qi}\hat{\theta}_{qic\tau} + h_{qi}\hat{A}_{ic\tau}\right] \\
&+ \quad \pi_2\sum_{r}^{Q}\eta_{r,i}\left[g_{ri}\hat{\theta}_{ric\tau} + h_{ri}\hat{A}_{ic\tau}\right] \\
&+ \quad \pi_3\sum_{j}^{I}\eta_{j,q}\left[g_{qj}\hat{\theta}_{qjc\tau} + h_{qj}\hat{A}_{ic\tau}\right] \\
&+ \quad \pi_4\sum_{j,r}^{I\cdot Q}\eta_{rj}\left[g_{rj}\hat{\theta}_{rjc\tau} + h_{rj}\hat{A}_{jc\tau}\right],
\end{aligned} \tag{15}$$

where the π_1-π_4 are occupation-industry-specific constant terms obtained from the linear approximation.

The paper proposes to use the following instruments

$$IV^{CITY,BETWEEN} = \sum_{j,r}^{I\cdot Q}\nu_{rj(\tau-1)}\Delta\hat{\eta}_{rjc\tau} \quad \text{and} \quad IV^{CITY,WITHIN} = \sum_{j,r}^{I\cdot Q}\hat{\eta}_{rjc\tau}\Delta\nu_{rj\tau},$$

where $\hat{\eta}_{rjc\tau}$ is predicted employment in a particular rjc cell as a share of city c predicted employment. The conditions ensuring the validity of these instruments is similar to (13) and (14) but use predicted employment shares in place of actual employment shares. Specifically, these conditions are

$$\lim_{I,Q,C\to\infty} \frac{1}{I}\frac{1}{Q}\frac{1}{C}\sum_{c}^{C}\left[\Delta\hat{\eta}_{rjc\tau}\sum_{i}^{I}\sum_{q}^{Q}\Delta\xi_{qic\tau}\right] = 0 \tag{16}$$

and

$$\lim_{I,Q,C\to\infty} \frac{1}{I}\frac{1}{Q}\frac{1}{C}\sum_{c}^{C}\left[\hat{\eta}_{rjc\tau}\sum_{i}^{I}\sum_{q}^{Q}\Delta\xi_{qic\tau}\right] = 0. \tag{17}$$

Since predicted employment shares are constructed using start-of-period occupation-industry-city employment, these conditions require that past and changes in past occupation-industry-city employment is uncorrelated with future shocks to the city-specific productivity components that are left in the error term.

F Industries, occupations and cities

Table 1: Industrial classification, 16 categories.

Primary sector	**Tertiary sector**
Industry 1	*Industry 9*
Agriculture, hunting, forestry and fishing	Wholesale, trade and commission excl. motor vehicles
Mining and quarrying	
Electricity, gas and water supply	*Industry 10*
	Sale of automotive fuel
Secundary sector	Retail trade excl. motor vehicles - repair of household goods
Industry 2	
Wood and products of wood and cork	*Industry 11*
Pulp, paper, paper products, printing and publishing	Transport storage and communications
Chemical, rubber, plastics and fuel products	
Basic metals and fabricated metal products	*Industry 12*
Other non-metallic mineral products	Finance, insurance, real estate and business services
Industry 3	*Industry 13*
Machinery and equipment (nec)	Hotels and restaurants
Motor vehicles, trailers and semi-trailers	Recreational, cultural and sporting activities
	Other service activities
Industry 4	Private households with employed persons
Electrical and optical equipment	
Other transport equipment	*Industry 14*
	Education
Industry 5	Health and social work
Textiles and textile products	
Leather, leather products and footwear	*Industry 15*
Other non-metallic mineral products	Sewage and refuse disposal, sanitation and similar activities
Manufacturing n.e.c.	Activities of membership organizations (nec)
Industry 6	*Industry 16*
Food products, beverages and tobacco	Public admin. and defense - compulsory social security
	Extra-territorial organizations and bodies
Industry 7	
Construction trades	
Industry 8	
Finishing trades	

Source: The IAB anonymized sample.

Table 2: Occupational classification, 33 categories.

Agricultural
Farming, forestry, gardening, fishing

Mining and quarrywork
Mining and quarrywork

Manufacturing
Stone, jewelery, brickwork
Glass and ceramics
Chemicals, plastics and rubber
Paper and printing
Woodwork
Metalworkers, primary product
Skilled metal work and related
Electrical
Metal and assembly / installation
Textiles
Leather goods
Food, drink and tobacco
Construction
Building
Carpenters
Painters
Goods sorters, packagers
Assistants
Machine operators

Technicians
Technicians - engineers and related
Technicians - manufacturing and science

Services and professionals
Buying and selling
Banking, insurance, agents
Arts, creative and recreational
Other services, personal and leisure services
Travel and transport
Administration and bureaucracy
Public order, safety and security
Health services
Teaching and social employment

Other
Other occupations

Source: The IAB anonymized sample.

Table 3: Urban centers of the local labour markets, except for areas with more than one urban center (marked with a *).

Aarchen	Münster
Augsburg	Nürnberg-Fürth-Erlangen
Bielefeld	Oldenburg
Braunschweig-Salzgitter	Osnabrück
Bremen	Paderborn
Bremerhaven	Pforzheim
Freiburg im Breisgau	Regensburg
Göttingen	Region Hannover
Hamburg	Rhein-Main*
Heilbronn	Rhein-Neckar*
Hildesheim	Rheinschiene*
Ingolstadt	Ruhr*
Kaiserlautern	Siegen
Karlsruhe	Saarbrücken
Kassel	Stuttgart-Reutlingen
Kiel	Trier-Saarburg and KS Trier
Koblenz	Ulm
Lübeck	Wolfsburg and Helmstadt
München	Wüzburg

Note: Local labour markets are defined by commuting areas according to the Federal Office for Building and Regional Planning.

G Other industrial and occupational classifications

Table 1: Industrial classification, 6 categories.

Primary sector	**Tertiary sector**
Industry 1	*Industry 5*
Agriculture, hunting, forestry and fishing	Wholesale, trade and commission excl. motor vehicles
Mining and quarrying	Sale of automotive fuel
Electricity, gas and water supply	Retail trade excl. motor vehicles - repair of household goods
	Transport storage and communications
Secundary sector	
Industry 2	*Industry 6*
Wood and products of wood and cork	Finance, insurance, real estate and business services
Pulp, paper, paper products, printing and publishing	Hotels and restaurants
Chemical, rubber, plastics and fuel products	Recreational, cultural and sporting activities
Basic metals and fabricated metal products	Other service activities
Other non-metallic mineral products	Private households with employed persons
Machinery and equipment (nec)	Education
Motor vehicles, trailers and semi-trailers	Health and social work
Electrical and optical equipment	Sewage and refuse disposal, sanitation and similar activities
Other transport equipment	Activities of membership organizations (nec)
	Public admin. and defense - compulsory social security
Industry 3	Extra-territorial organizations and bodies
Textiles and textile products	
Leather, leather products and footwear	
Other non-metallic mineral products	
Manufacturing n.e.c.	
Food products, beverages and tobacco	
Industry 4	
Construction trades	
Finishing trades	

Table 2: Industrial classification, 10 categories.

Primary sector	**Tertiary sector**
Industry 1	*Industry 5*
Agriculture, hunting, forestry and fishing	Wholesale, trade and commission excl. motor vehicles
Mining and quarrying	Sale of automotive fuel
Electricity, gas and water supply	Retail trade excl. motor vehicles - repair of household goods
Secundary sector	*Industry 6*
Industry 2	Transport storage and communications
Wood and products of wood and cork	
Pulp, paper, paper products, printing and publishing	*Industry 7*
Chemical, rubber, plastics and fuel products	Finance, insurance, real estate and business services
Basic metals and fabricated metal products	
Other non-metallic mineral products	*Industry 8*
Machinery and equipment (nec)	Hotels and restaurants
Motor vehicles, trailers and semi-trailers	Recreational, cultural and sporting activities
Electrical and optical equipment	Other service activities
Other transport equipment	Private households with employed persons
Industry 3	*Industry 9*
Textiles and textile products	Education
Leather, leather products and footwear	Health and social work
Other non-metallic mineral products	
Manufacturing n.e.c.	*Industry 10*
Food products, beverages and tobacco	Sewage and refuse disposal, sanitation and similar activities
	Activities of membership organizations (nec)
Industry 4	Public admin. and defense - compulsory social security
Construction trades	Extra-territorial organizations and bodies
Finishing trades	

Table 3: Occupational classification, 10 categories.

Agricultural
Occupation 1
Farming, forestry, gardening, fishing

Mining and quarrywork
Occupation 2
Mining and quarrywork

Manufacturing
Occupation 3
Stone, jewelery, brickwork
Glass and ceramics
Chemicals, plastics and rubber
Paper and printing
Woodwork
Metalworkers, primary product
Skilled metal work and related
Electrical
Metal and assembly / installation

Occupation 4
Textiles
Leather goods
Food, drink and tobacco

Occupation 5
Construction
Building
Carpenters
Painters
Goods sorters, packagers
Assistants
Machine operators

Technicians
Occupation 6
Technicians - engineers and related
Technicians - manufacturing and science

Services and professionals
Occupation 7
Buying and selling
Banking, insurance, agents
Arts, creative and recreational
Other services, personal and leisure services

Occupation 8
Travel and transport
Administration and bureaucracy
Public order, safety and security

Occupation 9
Health services
Teaching and social employment

Other
Occupation 10
Other occupations

Table 4: Occupational classification, 16 categories.

Agricultural	Building
Occupation 1	Carpenters
Farming, forestry, gardening, fishing	Painters
	Goods sorters, packagers
Mining and quarrywork	Assistants
Occupation 2	Machine operators
Mining and quarrywork	
	Technicians
Manufacturing	*Occupation 10*
Occupation 3	Technicians - engineers and related
Stone, jewelery, brickwork	Technicians - manufacturing and science
Glass and ceramics	
Chemicals, plastics and rubber	**Services and professionals**
	Occupation 11
Occupation 4	Buying and selling
Paper and printing	Banking, insurance, agents
Woodwork	Other services, personal and leisure service
Occupation 5	*Occupation 12*
Metal workers, primary product	Travel and transport
Skilled metal work and related	
	Occupation 13
Occupation 6	Administration and bureaucracy
Electrical	Public order, safety and security
Metal and assembly / installation	
	Occupation 14
Occupation 7	Arts, creative and recreational
Textiles	
Leather goods	*Occupation 15*
	Health services
Occupation 8	Teaching and social employment
Food, drink and tobacco	
	Other
Occupation 9	*Occupation 16*
Construction	Other occupations

H Robustness analysis

This Section performs a range of additional regressions to test the robustness of the baseline results.

Industrial and occupational aggregation The model assumes that the mobility parameters φ^{IND} and φ^{OCC} are independent of the classification of occupations and industries. However, since the cost of moving across industries and occupations is increasing in industrial and occupational distance, the coefficients of interest may be a decreasing function of the aggregation degree of industries and occupations. If the aggregation level is too high, $\varphi^{IND} \to 1$ and $\varphi^{OCC} \to 1$ and the spillover effect may disappear.

Table 5 investigates how results behave under various levels of industrial and occupational aggregation. Column (1) reproduces the baseline specification with 16 industries and 33 occupations. Columns (2), (3), (4), and (5) present results based on $16*16$, $10*10$, $6*16$ and $6*6$ classifications, respectively.[2]

Results for the $16*16$ classification are close to the $33*16$ baseline classification, with a slight decrease in the coefficients of industrial and occupational composition indices. This suggests that the average distance across occupations in a $33*16$ and $16*16$ classification is similar. As expected, when switching to higher degrees of aggregation, as shown in columns (3)-(5), the effect of a shift in industrial and occupational composition, as respectively captured by the coefficients on $R^{IND}_{qc\tau}$ and $R^{OCC}_{ic\tau}$, disappear. The coefficient on the city composition index remains statistically insignificant over the specifications but becomes very noisy with aggregation degrees beyond the $10*10$ classification. For this reason, the implied mobility parameters are imprecisely measured in columns (3)-(5).

For the $16*33$ classification, estimated mobility parameters suggest that mobility is higher across occupations – a result which is likely to be induced by the aggregation level of industries being twice that of occupations. In the case of the $16*16$ classification – where mobility parameters are more comparable – estimates (which do statistically significantly differ from each other, with a p-value on $H0 : \varphi^{IND} = \varphi^{OCC}$ of 0.046) still indicate that mobility across occupations exceeds

[2] Except for the classification into 6 industries, no broader official classifications exist. Thus, the other broader reclassifications of industries and occupations are made by the author. The industrial classification into 6 and 10 categories are shown in Section G, Tables 1-2, of the Web Appendix. The occupational classification into 10 and 16 categories are shown in Section G, Tables 3-4, of the Web Appendix.

mobility across industries. This implies that the sectoral wage spillover effect from shifts in the composition of within-industry employment is at least as important as the one resulting from a shift in industrial composition, and should therefore not be omitted.

Table 5: Industrial and occupational aggregation.

Dependent variable	Δ *log* $w_{qic\tau}$				
Regressors	**(1)** 16X33	**(2)** 16X16	**(3)** 10X10	**(4)** 6X16	**(5)** 6X6
$\Delta\ R^{IND}_{qc\tau}$	1.072***	0.820**	−0.070	−0.039	−0.403
	(0.271)	(0.388)	(0.748)	(0.654)	(0.993)
$\Delta\ R^{OCC}_{ic\tau}$	2.750***	2.618***	2.690	1.614	0.880
	(0.533)	(0.909)	(1.653)	(1.627)	(1.878)
$\Delta\ R^{CITY}_{c\tau}$	0.647	1.198	−2.984	1.895	−0.035
	(1.140)	(1.104)	(2.897)	(2.243)	(6.161)
$\Delta\ ER_{c\tau}$	0.281	0.509	0.441	0.395	0.385
	(0.410)	(0.433)	(0.283)	(0.265)	(0.398)
Implied φ^{IND}	0.810	0.686	−9.150	0.460	1.041
Implied φ^{OCC}	0.624	0.406	0.023	−0.021	0.920
H0: $\beta_1 = \beta_2$	[0.005]	[0.062]	[0.155]	[0.375]	[0.548]
F-first stage: $\Delta\ R^{IND}_{qc\tau}$	620	408	433	244	152
F-first stage: $\Delta\ R^{OCC}_{ic\tau}$	201	242	232	129	95
F-first stage: $\Delta\ R^{CITY}_{c\tau}$	262	441	121	165	165
F-first stage: $\Delta\ ER_{c\tau}$	22	21	18	18	10
Hansen	0.220	0.193	0.231	0.432	0.349
Observations	9376	7439	4172	2767	1408

Notes: All estimations contain $d_{qi\tau}$. Standard errors are clustered at the city level. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Selection into cities and occupations The baseline estimates rely on the assumption that the sample is a random draw of the population. In practice however, workers tend to self-select into cities according to unobserved earnings-related reasons. If worker selection is correlated with unobserved determinants of wages (e.g. individual abilities), the conditional mean error term will not be zero. The estimates of the coefficients on the composition indices will be inconsistent if the structure of employment within cities is correlated with worker selection decisions into cities. Like Beaudry et al. (2012), the paper uses Dahl (2002)'s non-parametric approach to correct for sample selection bias.

Let d_{kct} be a dummy taking the value of one if individual k works in city c at time t and let $E\left[\xi_{kqict}|d_{kct}=1\right]$ be the conditional mean error term. d_{kbct} is a dummy variable taking the value of one if individual k born in city b is working in city c at time t. Let Pr_{kbct} and Pr_{kbbt} be the probabilities that individual k born in city b is observed in city c and remains in city b at time t, respectively. Following Dahl (2002), the conditional mean error term can be identified as a function of worker migration probabilities Pr_{kbct} and Pr_{kbbt}. For movers it is

$$E\left[\xi_{kqict}|d_{kct}=1\right]=\sum_{b}d_{kbct}\left(Pr_{kbct}^{2}+Pr_{kbbt}^{2}\right)+\iota_{kqict},$$

while for stayers it is

$$E\left[\xi_{kqict}|d_{kct}=1\right]=\sum_{b}d_{kbct}Pr_{kbbt}^{2}+\iota_{kqict},$$

where ι is a zero-mean residual term. The sample selection bias is corrected by introducing $\sum_{b}d_{kbct}\left(Pr_{kbct}^{2}+Pr_{kbbt}^{2}\right)$ and $\sum_{b}d_{kbct}Pr_{kbbt}^{2}$ in the wage premium estimations.

Let individuals be divided into cells according to their observed characteristics (i.e. age, gender, nationality, education). Within the cell which is relevant for individual k, the migration probabilities are computed as follows

$$Pr_{kbct}=\frac{N_{bct}}{N_{bt}}\quad\text{and}\quad Pr_{kbbt}=\frac{N_{bbt}}{N_{bt}},$$

where N_{bt} is the number of individuals born in city b observed in the sample at time t, N_{bbt} is the number of individuals born in city b and still observed in city b and N_{bct} is the number of individuals born in city b but observed in city c, at time t. Within each cell, differences in P_{kbct} across movers being observed in city c are due to variations in the city of birth across workers. If the city of birth is not directly correlated to individual wages, differences in probabilities across movers of the same cell reflect differences in their unobserved abilities. Taking BGS case in point,

> [...] a person born in Pennsylvania has a lower probability of being observed in Seattle than a person born in Oregon. If both are observed living in Seattle, then we are assuming that

> the person from Pennsylvania must have a larger Seattle specific "ability" (a stronger earnings reason for being there) and this is what is being captured by the sample correction.[3]

The IAB anonymized sample does not provide data on workers city of birth. Instead, workers city of residence at $(t-1)$ is used as a source of variation across workers within cells, i.e. the paper assumes that where movers where living at $(t-1)$ does not affect their wage determination at time t.[4] The paper addresses the issue of self-selection into occupations in a similar way.

Results are shown in Table 6. Column (1) shows the baseline estimates. Columns (2) and (3) present results for specifications that control for selection into cities and occupations, respectively. The point estimates on the industrial and occupational composition indices remain stable and statistically significant at the 1% level. Even though they remain statistically insignificant and positive, the estimates on the city composition index are reduced considerably, suggesting that they were capturing part of the self-selection effect across cities. Regarding the estimated mobility parameters, they remain similar to the baseline specification. Overall, correcting for sample selection bias does not substantially affect the results.

[3] Beaudry et al. (2012)

[4] The choice of one lag for workers city of residence is arbitrary. Estimates remain similar if five lags are used.

Table 6: Selection.

Dependent variable	$\Delta\ log\ w_{qic\tau}$		
Regressors	**(1)** Baseline	**(2)** City Selection	**(3)** Occupation Selection
$\Delta\ R_{c\tau}^{CITY}$	0.647	0.232	0.307
	(1.140)	(1.543)	(1.194)
$\Delta\ R_{qc\tau}^{IND}$	1.072***	1.106***	1.303***
	(0.271)	(0.211)	(0.247)
$\Delta\ R_{ic\tau}^{OCC}$	2.750***	3.172***	2.334***
	(0.533)	(0.775)	(0.418)
$\Delta\ ER_{c\tau}$	0.281	0.032	0.198
	(0.410)	(0.377)	(0.419)
Implied φ^{IND}	0.810	0.932	0.884
Implied φ^{OCC}	0.624	0.826	0.809
H0: $\beta_1 = \beta_2$	[0.005]	[0.007]	[0.024]
F-first stage: $\Delta\ R_{c\tau}^{CITY}$	262	221	305
F-first stage: $\Delta\ R_{qc\tau}^{IND}$	620	1976	1861
F-first stage: $\Delta\ R_{ic\tau}^{OCC}$	201	271	241
F-first stage: $\Delta\ ER_{c\tau}$	22	22	22
Hansen	0.220	0.564	0.224
Observations	9376	9376	9376

Notes: All estimations contain $d_{qi\tau}$. Standard errors are clustered at the city level. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. p-values in brackets.

Identification issue The identification strategy hinges on the assumption that national employment and changes in national employment, in a particular occupation-industry cell, are uncorrelated to present and future city-specific idiosyncratic shocks on wages. To test for the validity of this assumption, the paper predicts city-level employment in a particular occupation and industry using French employment growth. If the identification strategy is valid, then using French employment growth to construct instruments should not alter the estimates.[5]

Results are presented in Table 7. Columns (1) shows the baseline results. Column (2) shows IV results for the specification that uses French occupation-industry employment growth to create instruments. Results lend support to the identification strategy. The point estimates are very close to the baseline specification. The coefficients on composition indices increase slightly. The coefficients on the industrial and occupational composition indices remain significant with p-values smaller than 0.01. Even though they decrease somewhat, the estimated parameters φ^{IND} and φ^{OCC} remain high, suggesting significant mobility costs.

[5]Data source: INSEE French employment survey, 1975-2002 period.

Table 7: Instrumenting with French data.

Dependent variable	$\Delta\ log\ w_{qic\tau}$	
Regressors	**(1)** Baseline	**(2)** French data
$\Delta\ R^{IND}_{qc\tau}$	1.072***	1.123***
	(0.271)	(0.326)
$\Delta\ R^{OCC}_{ic\tau}$	2.750***	3.141***
	(0.533)	(0.710)
$\Delta\ R^{CITY}_{c\tau}$	0.647	1.007
	(1.140)	(1.334)
$\Delta\ ER_{c\tau}$	0.281	0.247
	(0.410)	(0.438)
Implied φ^{IND}	0.810	0.757
Implied φ^{OCC}	0.624	0.527
H0: $\beta_1 = \beta_2$	[0.005]	[0.008]
F-first stage: $\Delta\ R^{IND}_{qc\tau}$	620	161
F-first stage: $\Delta\ R^{OCC}_{ic\tau}$	201	56
F-first stage: $\Delta\ R^{CITY}_{c\tau}$	262	108
F-first stage: $\Delta\ ER_{c\tau}$	22	11
Hansen	0.220	0.142
Observations	9376	8907

Notes: All estimations contain $d_{qi\tau}$. Standard errors are clustered at the city level. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. p-values in brackets.

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