

APPENDIX: SECULAR LABOR REALLOCATION AND BUSINESS CYCLES

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A. Comparison of R_a to Other Measures

In a seminal paper, [Lilien \(1982\)](#) measures sectoral dispersion as a weighted standard deviation of industry employment growth rates,

$$R_{a,t,t+1}^{\text{Lilien}} = \left[\sum_{i=1}^I s_{a,i,t} (\Delta \ln e_{a,i,t+1} - \Delta \ln e_{a,t+1})^2 \right]^{\frac{1}{2}}. \quad (\text{A.1})$$

To illustrate the differences from our measure $R_{a,t,t+j}$ defined in equation (1) of the main text, we rewrite Lilien's measure using an absolute value metric rather than a Euclidean metric,

$$R_{a,t,t+1}^{\text{Lilien-absolute}} = \sum_{i=1}^I s_{a,i,t} |\Delta \ln e_{a,i,t+1} - \Delta \ln e_{a,t+1}|, \quad (\text{A.2})$$

and take a first order approximation of equation (A.2) around $g_{a,i,t,t+1} = 0 \forall i$, yielding

$$R_{a,t,t+1}^{\text{Lilien-absolute}} \approx \sum_{i=1}^I s_{a,i,t} \left| \frac{g_{a,i,t,t+1} - g_{a,t,t+1}}{1 + g_{a,t,t+1}} \right| = \frac{2}{12} R_{a,t,t+1}. \quad (\text{A.3})$$

Comparing equations (1), (A.1) and (A.3), up to a first order approximation our measure differs from Lilien's only in the choice of metric.

Our measure also has a close connection to the job reallocation rate defined by [Davis and Haltiwanger \(1992, p. 828\)](#),¹

$$R_{a,t,t+1}^{\text{D-H}} = \frac{1}{0.5(e_{at+1} + e_{at})} \sum_{i=1}^I |e_{a,i,t+1} - e_{a,i,t}| \quad (\text{A.4})$$

$$= \sum_{a=1}^I \bar{s}_{a,i,t,t+1} |g_{a,i,t,t+1}^{\text{sym}}|, \quad (\text{A.5})$$

where $\bar{s}_{a,i,t,t+1} \equiv \frac{(e_{a,i,t+1} + e_{a,i,t})}{(e_{a,t+1} + e_{a,t})}$ is the two period average employment share, and $g_{a,i,t,t+1}^{\text{sym}} \equiv \frac{(e_{a,i,t+1} - e_{a,i,t})}{0.5(e_{a,i,t+1} + e_{a,i,t})}$ is the symmetric growth rate of employment of industry i in area a . To illustrate the relationship between $R_{a,t,t+1}^{\text{D-H}}$ and our measures, we rewrite the full recession-recovery cycle reallocation measure in the case where employment at peak and at last-peak are exactly equal, $e_{a,t+T} = e_{a,t}$, as,

$$R_{a,t,t+T} = \frac{12}{T} \frac{1}{2} \sum_{i=1}^I \bar{s}_{a,i,t} |g_{a,i,t+T}|.$$

¹Davis and Haltiwanger call this term SUM_t . In their application a corresponds to a sector, i to an establishment and I to the total number of establishments in that sector.

Thus, up to the scale normalization, our measure coincides exactly with the [Davis and Haltiwanger \(1992\)](#) measure evaluated over a full cycle rather than period-by-period.

B. Relationship Between Predicted Reallocation and Covariates

In this Appendix we provide further detail of the area-specific time-varying control variables. We also report partial correlations with predicted reallocation and a version of table 5 of the main text showing the coefficients on the control variables.

The MSA/CSA level variables include employment growth over the 4 years before the cycle start; trend growth of the working-age population, measured as the log change between 5 and 1 years before the cycle start in the population of persons age 15-69;² house price growth over the 4 years before the cycle start;³ area size, measured by the log of sample mean employment; and the Herfindahl of industry employment concentration at the cycle start.

Table C.1 reports correlations of Bartik predicted employment with these variables after separately pooling over national recession-recovery cycles and national expansion cycles, and partialling out national month fixed effects and the predicted growth rate.⁴

We next repeat the results from table 5 reporting the coefficients and standard errors on the control variables.

²We interpolate annual county-level population data from the Census Bureau to obtain a monthly series of population. We measure the trend up to 1 year before the cycle change to ensure the population trend does not incorporate data realizations after the cycle change.

³We construct area house price indexes using the Freddie Mac MSA house price indexes, available beginning in 1975. For CSAs combining multiple MSAs, we construct a CSA index as a geometric weighted average of the MSA indexes, using 1990 employment as weights. Noting that our data start in 1975 and the first national recession begins in 1980, we use a 4 year change to minimize loss of observations while still allowing for business cycle frequency lag length.

⁴The correlation of Bartik predicted reallocation and Bartik predicted employment after partialling out the national month fixed effects is -0.32 in an expansion and -0.59 in a recession-recovery.

Table C.1 – Correlation of Predicted Reallocation With Other Variables

	Dependent variable: Bartik reallocation per year					
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: recession-recovery cycles:						
$\Delta \ln e_{t-48,t}$	-0.040 ⁺ (0.021)					-0.0042 (0.0064)
$\Delta \ln l_{t-60,t-12}$		-0.053** (0.018)				-0.011* (0.0056)
$\Delta \ln HPI_{t-48,t}$			0.022 (0.018)			0.012* (0.0049)
Log of mean employment				0.021 (0.016)		0.0019 (0.0033)
Herfindahl at peak					-0.051 (0.032)	-0.0094 (0.0080)
Observations	748	748	748	748	748	748
Panel B: expansion cycles:						
$\Delta \ln e_{t-48,t}$	-0.033 (0.041)					0.010 (0.0065)
$\Delta \ln l_{t-60,t-12}$		0.021 (0.058)				0.0092 (0.0078)
$\Delta \ln HPI_{t-48,t}$			-0.13** (0.037)			-0.025** (0.0043)
Log of mean employment				0.21** (0.043)		0.026** (0.0055)
Herfindahl at peak					-0.13** (0.042)	-0.012* (0.0051)
Observations	557	557	557	557	557	557

Notes: Each dependent and independent variable shown is first regressed on month fixed effects and predicted employment growth and then replaced with the residual from this regression and standardized to have unit variance. Standard errors in parentheses and clustered by CSA-MSA.

Table C.2 – Heterogeneous Effects over Cycle

	Dep. var.: change in unemployment rate					
	Recession-Recovery			Expansion		
	(1)	(2)	(3)	(4)	(5)	(6)
Right hand side variables:						
Reallocation	0.87** (0.25)	0.87** (0.23)	0.91** (0.21)	-0.40 (0.35)	-0.10 (0.16)	-0.32 (0.34)
Predicted growth over cycle	0.38 ⁺ (0.22)	0.22 (0.21)	0.42 (0.37)	-0.35 ⁺ (0.19)	-0.11 (0.18)	-0.81* (0.36)
Predicted growth at horizon	-0.71** (0.15)	-0.56** (0.14)	-0.70** (0.19)	0.14 ⁺ (0.08)	0.013 (0.07)	0.15 (0.09)
$\Delta \ln e_{t-48,t}$		-0.009 (0.007)			0.016** (0.005)	
$\Delta \ln l_{t-60,t-12}$		-0.002 (0.001)			0.003 (0.007)	
$\Delta \ln HPI_{t-48,t}$		0.90** (0.27)			0.56** (0.17)	
Log of mean employment		0.22** (0.05)			-0.03 (0.03)	
Herfindahl		0.46 (0.30)			0.22 (0.28)	
National cycle FE	Yes	Yes	Yes	Yes	Yes	Yes
Area FE	No	No	Yes	No	No	Yes
CSA-MSA clusters	218	218	218	218	218	218
First stage coefficient	1.01	1.06	1.28	0.66	1.28	0.98
First stage F-statistic	16.7	20.2	13.3	8.5	66.7	15.4
First stage observations	534	534	534	557	557	557
Second stage observations	748	748	748	557	557	557

Notes: Notes: The table reports the full set of coefficients (excluding categorical variables) for the regressions reported in table 5 in the main text. Standard errors in parentheses and clustered by CSA-MSA. ** indicates significance at the 1% level. Standard errors in parentheses and clustered by CSA-MSA. ** indicates significance at the 1% level.

C. Model appendix

C.1. Aggregation

Consumers across all islands combine industry goods sold at price $P_{a,j,t}$ using a CES aggregator, such that total output of island a is given by

$$Y_{a,t} = \left[\int_{j=0}^1 Q_{a,j,t}^{\frac{\xi-1}{\xi}} dj \right]^{\frac{\xi}{\xi-1}},$$

implying the demand function

$$Q_{a,j,t} = \left(\frac{P_{a,j,t}}{P_{a,t}} \right)^{-\xi} Y_{a,t},$$

and where $P_{a,t} = \left[\int_{j=0}^1 (P_{a,j,t})^{1-\xi} \right]^{\frac{1}{1-\xi}}$ is the local producer price index.

C.2. Trade and market clearing

The local consumption is a CES aggregate of goods produced in all regions of the currency union:

$$C_{a,t} = \left[\sum_b \tilde{\tau}_{ab,t}^{\frac{1}{\varphi}} C_{ab,t}^{\frac{\varphi-1}{\varphi}} \right]^{\frac{\varphi}{\varphi-1}},$$

where $C_{ab,t}$ denotes consumption in island a of the composite retail good produced on island b .

The law of one price holds, implying the demand functions

$$C_{ab,t} = \tilde{\tau}_{ab,t} \left(\frac{P_{b,t}}{P_{a,t}^C} \right)^{-\varphi} C_{a,t},$$

where $P_{a,t}^C = \left[\sum_b \tilde{\tau}_{ab,t} (P_{b,t})^{1-\varphi} \right]^{\frac{1}{1-\varphi}}$ is the local consumer price index. Thus, consumer price indices across islands may differ if the consumption weights $\tilde{\tau}_{ab,t}$ differ as a result of, *inter alia*, home bias in consumption.

Market clearing in the final goods market requires

$$\sum_a C_{ab,t} = Y_{b,t} \forall b.$$

C.3. Financial markets

Financial markets are incomplete across areas. The only financial instrument that can be traded is a one-period nominal bond. We let $B_{a,t}$ denote total local holdings of the bond. The nominal interest rate on the bond, $R_t + \tilde{\mu}_{a,t}$, includes a spread $\tilde{\mu}_{a,t}$ over the gross nominal interest rate set by the central bank R_t . We follow [Schmitt-Grohé and Uribe \(2003\)](#) and let the interest rate wedge $\tilde{\mu}_{a,t}$ respond to the local asset position:

$$\tilde{\mu}_{a,t} = \mu_t - \rho_\mu \frac{B_{a,t}}{P_{a,t}},$$

where $\rho_\mu > 0$ but small. This formulation ensures a stationary steady state for local areas under incomplete markets. The component μ_t is exogenous and common to all areas. We use a shock to μ_t to simulate a demand-induced recession.

The per capita nominal domestic net financial asset position then evolves according to:

$$\frac{B_{a,t}}{l_{a,t}} = (1 + R_t + \tilde{\mu}_{a,t} - \lambda_{a,t}^A) dl_{a,t}^{-1} \frac{B_{a,t-1}}{l_{a,t-1}} + \frac{P_{a,t} Y_{a,t}}{l_{a,t}} - \frac{P_{a,t}^C (C_{a,t} + I_{a,t})}{l_{a,t}} + \pi_{a,t-1}^A \sum_{b=1}^A \lambda_{b,t}^A \frac{l_{b,t}}{l_{a,t}} dl_{b,t}^{-1} \frac{B_{b,t-1}}{l_{b,t-1}},$$

where $dl_{a,t} = l_{a,t}/l_{a,t-1}$ denotes gross population growth in area a ($dl_{a,t} = 0$ in our baseline model). Zero net supply of bonds at all times implies the market clearing condition, $\sum_a B_{a,t} = 0$. We set initial bond allocations to zero for all areas, $B_{a,0} = 0 \forall a$.

C.4. Government policy

The central bank follows a standard interest rate rule that obeys the Taylor principle:

$$R_t = \beta^{-1} (\Pi_t^C)^{\phi_\pi}, \quad \phi_\pi > 1,$$

where $\Pi_t^C = \prod_{a=1}^A (\Pi_{a,t}^C)^{\frac{l_{a,t}}{l}}$ is a population-weighted geometric average of local consumer price inflation rates. In the $A = 2$ small-large calibration, the nominal interest rate R_t evolves exogenously with respect to local economic conditions in the small area, $R_t = \beta^{-1} (\Pi_{b,t}^C)^{\phi_\pi}$.

C.5. Household optimization problem

Finally, each island resident has instantaneous utility $u(C_{a,t}/l_{a,t})$, where $C_{a,t}/l_{a,t}$ is consumption per capita. The representative household on an island maximizes the expected discounted sum of total per-period utility accruing to the residents of the island each period and subject to a flow budget constraint:

$$\begin{aligned} & \max \sum_{s=0}^{\infty} D^s l_{a,t+s} u(C_{a,t+s}/l_{a,t+s}) \\ \text{s.t. } & P_{a,t}^C C_{a,t} + B_{a,t+1} = \sum_i w_{a,i,t} e_{a,i,t} + (l_{a,t} - e_{a,t}) P_{a,t} z + (R_{t-1} + \tilde{\mu}_{a,t-1}) B_{a,t} - T_{a,t}, \end{aligned}$$

where the period utility function takes the form $u(C_{a,t+s}/l_{a,t+s}) = (C_{a,t+s}/l_{a,t+s})^{1-\sigma}/(1-\sigma)$.

The island discount factor used in equations (11)–(14) is

$$m_{a,t,t+1} = D \frac{u'(C_{a,t+1}/l_{a,t+1})}{u'(C_{a,t}/l_{a,t})},$$

and the corresponding household first order condition is

$$\left[m_{a,t,t+1} \frac{R_t + \tilde{\mu}_{a,t}}{\Pi_{a,t+1}^C} \right] = 1.$$

C.6. Wage Rigidity

We implement the downward nominal wage constraint as follows. We first calculate the Nash-bargain job surplus J^* as

$$J_{a,t}^* = (1 - \beta)(J_{a,t} + W_{a,t} - U_{a,t}).$$

The implied Nash-bargain real wage in each industry is then,⁵

$$w_{a,i,t}^* = p_{a,i,t} - J_{a,t}^* + (1 - \delta)m_{a,t,t+1}J_{a,t+1}^*.$$

⁵Alternatively, we could implement the Nash solution also at $t+1$, so $w_{a,i,t}^* = p_{a,i,t} - J_{a,t}^* + (1 - \delta)m_{a,t,t+1}J_{a,t+1}^*$. Doing so has negligible impact on our quantitative results.

Table D.1 – Calibrated Parameters

Name	Description	Value	Source
<i>Matching process</i>			
f	Job finding rate	0.5	Monthly job finding rate
q	Job filling rate	0.75	Davis et al. (2013)
δ	Separation rate	0.066	Matched monthly CPS
λ^I	Industry reallocation rate	0.043	Matched monthly CPS
ρ^I	Industry reallocation noise	0.95	Kline (2008), Artuç et al. (2010), symmetry
D	Discount factor	0.9967	annual rate = 4%
β	Bargaining power	0.6	
χ^w	Downward-wage rigidity	0.0035	Average monthly nominal wage growth
z	Opportunity cost	0.55	p Chodorow-Reich and Karabarbounis (2016)
<i>Production</i>			
η	Steady-state productivity	$\frac{1}{12}$	Annualized MRP $p = 1$
<i>Preferences</i>			
σ	Inverse IES	0.5	
ζ	Elasticity of substitution over industries	4	Broda and Weinstein (2006)
τ_{ab}	Small area import share	0.3	Nakamura and Steinsson (2014)
φ	Elasticity of home vs foreign goods	2	Nakamura and Steinsson (2014)
<i>Policy</i>			
ϕ_π	Interest rate rule inflation response	2.5	
ν	NFA interest rate response to NFA	0.001	

We then check whether this Nash-bargain real wage violates the downward nominal wage constraint,

$$w_{a,i,t} = \max\{w_{a,i,t}^*, (1 - \chi^w) w_{a,i,t-1} / \Pi_{a,t}\}. \quad (\text{D.1})$$

C.7. Calibration

Table D.1 provides a summary of the calibrated parameters and moments matched. The remainder of the section provides details of our calibration.

For convenience we reproduce the key labor market equations (11)–(14) from the text:

$$J_{a,i,t} = (p_{a,i,t} - w_{a,i,t}) + (1 - \delta_t) m_{a,t,t+1} J_{a,i,t+1}, \quad [\text{text eq. (11)}]$$

$$W_{a,i,t} = w_{a,i,t} + m_{a,t,t+1} \left\{ [(1 - \delta_t) + (\delta_t - \lambda_t) f_{a,i,t+1}] W_{a,i,t+1} + (\delta_t - \lambda_t) (1 - f_{a,i,t+1}) U_{a,i,t+1} \right.$$

$$+ \lambda_{a,t}^I \left(\mathbf{E} \max_j \{ (1 - f_{a,j,t+1}) U_{a,j,t+1} + f_{a,j,t+1} W_{a,j,t+1} + \psi_j + \varepsilon_{jt} \} \right) \Bigg\},$$

[text eq. (12)]

$$U_{a,i,t} = z + m_{a,t,t+1} \left\{ (1 - \lambda_t) [f_{a,i,t+1} W_{a,i,t+1} + (1 - f_{a,i,t+1}) U_{a,i,t+1}] \right. \\ \left. + \lambda_{a,t}^I \left(\mathbf{E} \max_j \{ (1 - f_{a,j,t+1}) U_{a,j,t+1} + f_{a,j,t+1} W_{a,j,t+1} + \psi_j + \varepsilon_{jt} \} \right) \right\},$$

[text eq. (13)]

$$\kappa = q_{a,i,t} J_{a,i,t}.$$

[text eq. (14)]

Combining equations (12) and (13) provides a useful expression of the surplus to a worker from having a job:

$$W_{a,i,t} - U_{a,i,t} = w_{a,i,t} - z + m_{a,i,t} (1 - \delta_t) (1 - f_{a,i,t+1}) (W_{a,i,t+1} - U_{a,i,t+1}). \quad (\text{D.2})$$

We calibrate parameters to a monthly frequency. We set the worker's bargaining power β to 0.6 based on a matching efficiency of 0.4 and the Hosios condition. We set $D = 0.9967$ for an annual interest rate of 4%. We obtain a target for the steady state job finding rate f appropriate to a two state labor market model of 0.5 by updating the procedure described in [Shimer \(2012\)](#), and for the job filling rate q of 0.75 from [Davis et al. \(2013\)](#). Together these targets determine $\theta = f/q$, which in turn determines matching efficiency $M = f\theta^{\alpha-1}$. We use the longitudinally linked CPS to find a steady state separation rate inclusive of employed-to-unemployed transitions but exclusive of area movers of 0.062.⁶ In our baseline calibration we

⁶The CPS employs a rotating sample, wherein a selected address will participate in the survey for four consecutive months, not participate for eight months, and then reenter the sample for four more months. We use the longitudinal linkage file constructed by IPUMS and described by [Drew, Flood, and Warren \(2014\)](#) to match individual records across months. The CPS implemented referenced-based interviewing as part of the 1994 survey redesign. Of particular relevance, rather than asking all respondents the full set of employment status questions each month, respondents not in an incoming rotation group (i.e. not in their first or fifth month in the sample) and employed in the previous month first get asked whether they have changed employer (question Q25-CK) or job duties (question Q25DEP-2,3). Those reporting no change in employer or job duties have a number of fields automatically carried forward from the previous month, including industry of employment. Likewise, unemployed respondents have their previous industry carried forward if applicable; other unemployed respondents (except new entrants) report the industry of their previous place of employment. The adoption of reference-based interviewing sharply reduced the number of respondents reporting a change of industry each month. As a result, we restrict our sample to the post-1994 redesign period. We follow [Fallick and Fleischman \(2004\)](#) in discarding respondents in rotation groups 2 and 6 to correct for rotation group bias known to affect incoming rotation groups. Thus, we use the set of respondents not in an incoming rotation group in the reference

abstract from migration, so we slightly adjust upwards total separations to $\delta = 0.066$ to include the incidence of migration in the data from [Kaplan and Schulhofer-Wohl \(2017\)](#).⁷ We normalize aggregate $p = 1$ and set annualized z to 0.55, in the range suggested by [Chodorow-Reich and Karabarbounis \(2016\)](#).

We calibrate λ^I as follows. In steady state, there are δe new unemployed each period. The probability of switching industries conditional on a λ^I shock is $(I - 1)/I$ in steady-state. Of the newly unemployed,

$$\frac{(\delta - \lambda^I \frac{I-1}{I}) ef \left[1 + (1-f) \left(1 - \lambda^I \frac{I-1}{I} \right) + (1-f)^2 \left(1 - \lambda^I \frac{I-1}{I} \right)^2 + \dots \right]}{\delta ef \left[1 + (1-f) + (1-f)^2 + \dots \right]} = \frac{\frac{(\delta - \lambda^I \frac{I-1}{I})}{1 - (1-f) \left(1 - \lambda^I \frac{I-1}{I} \right)}}{\frac{\delta}{1 - (1-f)}} \quad (\text{D.3})$$

will not switch industries at least once before regaining employment. Thus, the share c of workers who go through an unemployment spell and cross industries is:

$$c = 1 - \frac{\frac{(\delta - \lambda^I \frac{I-1}{I})}{1 - (1-f) \left(1 - \lambda^I \frac{I-1}{I} \right)}}{\frac{\delta}{1 - (1-f)(1)}},$$

which given the values of I , δ and f described above, can be solved for λ^I . We use the CPS matched basic monthly files described in footnote 6 to find a c of 0.6 across NAICS 3 digit industries between 1994 and 2014, implying $\lambda^I = 0.039 \frac{I}{I-1}$. In our baseline calibration $I = 10$, so we set $\lambda^I = 0.043$.

We assume that the taste shocks $\varepsilon_{a,j,t}^I$ come from type 1 $\text{EV}(-\rho^I \tilde{\gamma}, \rho^I)$ distribution, where $\tilde{\gamma}$ is Euler's constant,

$$\varepsilon \sim \exp \left(-\frac{\varepsilon + \rho^I \tilde{\gamma}}{\rho^I} \right) \exp \left[-\exp \left(-\frac{\varepsilon + \rho^I \tilde{\gamma}}{\rho^I} \right) \right] \quad (\text{D.4})$$

The parameter ρ^I governs the variance of the taste shock and thus their importance in real-

or previous month in the longitudinally-linked CPS to obtain job finding rates, job separation rates, and the fraction of spells beginning and ending with employment which involve a change in NAICS 3 digit industry. We again use our constructed CPS-NAICS 3 crosswalk to map CPS industries into NAICS 3 digit industries.

⁷The CPS follows addresses rather than households. The longitudinal component therefore does not contain any movers. Thus, the separation rate calculated from the longitudinal component of the CPS is net of individuals who separate from their job and move. Likewise, in choosing the moment in equation (D.3) to compare to CPS data on industry switchers we consider only individuals who complete an employment-unemployment-employment spell within the same geographic area.

location decisions. We normalize the mean of the distribution to zero. Standard derivations imply:

$$\pi_{a,j,t}^I = \frac{\exp\left(\frac{X_{a,j,t+1}}{\rho^I}\right)}{\sum_{i=1}^I \exp\left(\frac{X_{a,i,t+1}}{\rho^I}\right)}, \quad (\text{D.5})$$

where $\pi_{a,j,t}^I$ denotes the probability of moving to industry j conditional on receiving a λ^I reallocation shock, $X_{a,j,t+1} = (1 - f_{a,j,t+1})U_{a,j,t+1} + f_{a,j,t+1}W_{a,j,t+1}$ is the value of searching (net of the taste shock) in industry j . Moreover, using properties of the type 1 EV distribution,

$$\mathbf{E} \max_j \{X_{a,j,t} + \psi_j + \varepsilon_j\} = \rho^I \ln \sum_j \exp\left(\frac{X_{a,j,t} + \psi_j}{\rho^I}\right). \quad (\text{D.6})$$

The parameter ρ^I governs the directedness of search of re-optimizers across industries. When $\rho^I = 0$ then search is fully directed, whereas when $\rho^I \rightarrow \infty$ then search is fully undirected. The standard deviation of the taste shock is equal to $\rho^I \frac{\pi}{\sqrt{6}}$. We infer ρ^I jointly with the aggregate shocks to match the average employment share changes, the average unemployment increase and duration of the cycle, and the peak cross-sectional effect of reallocation on unemployment in recessions. Heuristically, ρ^I is identified from the peak cross-sectional effect of reallocation on unemployment: if the cross-sectional estimates were small, we would infer ρ^I is small, and so the set of shocks inducing reallocations is also small. In that case, the downward wage constraint would not bind in the contracting sector and the model would produce a minimal decline in vacancies and mismatch unemployment. Conversely, large cross-sectional estimates require a large ρ^I and large shocks to generate a significant decline in vacancies and a divergence in labor market tightness. In our benchmark model, this procedure yields $\rho^I = 0.95$.

Our estimate of this parameter is within the (wide) range of existing estimates. For example, [Kline \(2008\)](#) uses an indirect inference procedure to estimate a standard deviation equivalent to about 2.5 weeks of steady state earnings, while [Artuç et al. \(2010\)](#) directly estimate it from data on wages and industry mobility and find a value of 5 years of steady state earnings. Our $\rho^I = 0.95$, implying that a standard deviation of the taste shock corresponds to 1.22 years of steady state earnings. This magnitude is in the bottom half of the range estimated in previous

work.

Adding together equations (11) and (D.2), setting the worker's share of match surplus to β , using the free entry condition (14), and the steady state condition $D = m_a$, and dropping t subscripts to denote steady state yields an expression for $\theta_{a,i}$ as an implicit function of parameters and the marginal revenue product $p_{a,i}$:

$$\frac{1}{1-\beta} \kappa M^{-1} \theta_{a,i}^\alpha = \frac{D^{-1}}{D^{-1} - (1-\delta)(1-\beta M \theta_{a,i}^{1-\alpha})} (p_{a,i} - z). \quad (\text{D.7})$$

Given already calibrated $\beta, D, \delta, \lambda, M, \theta, \psi, z$, equation (D.7) then determines κ .

We calibrate downward wage rigidity based on the 0.35% average monthly increase in hourly earnings of production and non-supervisory employees. Given that our model has neither productivity growth nor trend inflation, we set $\chi^w = 0.0035$. This allows nominal wages to fall by 0.35% each month relative to trend, which corresponds to zero nominal wage growth.

C.8. Solving for steady state

We solve for the steady-state in the currency union with a small member (a) and a much larger member (b). In both cases we posit an initial allocation of labor across industries $\{s_{a,i}\}_i$ and $\{s_{b,i}\}_i$. Then we find the $\{\tau_{a,i}, \psi_{a,i}\}_i$ and $\{\tau_{b,i}, \psi_{b,i}\}_i$ that implement this allocation, such that marginal products are equalized across all sectors and locations.

We first solve for the steady-state of the large (foreign) part of the currency union. The output, relative demand, and marginal product of each industry is given by,

$$\begin{aligned} Q_{b,i} &= \eta e_{b,i}, \\ Q_{b,i} &= \tau_{b,i} (P_{b,i}^Q)^{-\zeta} Q_b \\ p_{b,i} &= \eta P_{b,i}^Q \end{aligned}$$

where total output is,

$$Y_b = Q_b = \left[\sum_i \tau_{b,i}^{\frac{1}{\zeta}} (\eta_i e_{b,i})^{\frac{\zeta-1}{\zeta}} \right]^{\frac{\zeta}{\zeta-1}}.$$

To equalize marginal products across industries, we require

$$\frac{e_{b,i}}{\tau_{b,i}} = \frac{e_{b,j}}{\tau_{b,j}}$$

as well as $\sum_j \tau_{b,j} = 1$. This yields I restrictions.

In addition, inflows to each sector have to equal outflows,

$$\pi_{b,i}^I = \frac{\exp\left(\frac{X_{b,i,t} + \psi_i}{\rho^I}\right)}{\sum_j \exp\left(\frac{X_{b,j,t} + \psi_j}{\rho^I}\right)} = l_{b,i}.$$

where $\sum_i l_{b,i} \equiv 1$. Because marginal products are equalized across sectors, so will be tightness, wages, and job finding rates. Thus, $X_{a,i,t} = X_{a,j,t}$, and the above reduces to a simple condition:

$$\frac{\exp\left(\frac{\psi_{b,i}}{\rho^I}\right)}{\sum_j \exp\left(\frac{\psi_{b,j}}{\rho^I}\right)} = l_{b,i}.$$

This yields another $I - 1$ restrictions.

We normalize $\sum_j \exp\left(\frac{\psi_j}{\rho^I}\right) = 1$ to identify the unique solution to our problem given $\{s_{b,i}\}_i$,

$$\tau_{b,i} = s_{b,i}, \quad \psi_{b,i} = \rho^I \ln s_{b,i}$$

We can now solve for the allocation of labor across industries given our target job finding rate f_b ,

$$\begin{aligned} l_{b,i} &= s_{b,i} \\ x_{b,i} &= \frac{\delta}{f_b + \delta(1 - f_b)} l_{b,i} \\ u_{b,i} &= \frac{\delta(1 - f_b)}{f_b + \delta(1 - f_b)} l_{b,i} \\ e_{b,i} &= \frac{f_b}{f_b + \delta(1 - f_b)} l_{b,i} \end{aligned}$$

Given the allocation of labor, we can solve for $Q_{b,i}$ and Q_b . This in turn yields a common relative price using our solution for $\tau_{b,i}$

$$P_b^Q = \left(\frac{\eta e_{b,i}}{\tau_{b,i} Q_b}\right)^{-\zeta} = \left(\frac{\eta f_b}{f_b + \delta(1 - f_b) Q_b}\right)^{-\zeta}$$

and thus a common marginal product, $p_b = \eta P_b^Q$.

Next we solve for the remaining endogenous variables given this allocation of labor and the initial job finding rate.

We solve for tightness as the ratio of our target job finding and job filling rate,

$$\theta_b = \frac{f_b}{q_b},$$

which yields matching efficiency, $M = f_b \theta_b^{-(1-\theta)}$, and vacancy posting across sectors $v_{b,i} = \theta_b x_{b,i}$.

The free-entry condition for firms yields the job surplus,

$$J_b = \frac{\kappa}{q_b},$$

and from the Nash Bargaining solution we obtain total surplus,

$$S_b = \frac{J_b}{1-\beta}$$

Since total surplus is also the discounted marginal product net of disutility,

$$S_b = \frac{p_b - z}{1 - D^{-1}(1-\delta)(1-\beta f_b)},$$

which implies a steady-state real wage of,

$$w_b = z + \beta(p_b - z) \frac{D^{-1} - (1-\delta)(1-f_b)}{D^{-1} - (1-\delta)(1-\beta f_b)}.$$

The steady-state set of unemployment values solves

$$U_b = \frac{D^{-1}z + \theta_b \kappa \frac{\beta}{1-\beta}}{D^{-1} - 1},$$

and the worker value function solves,

$$W_b = \frac{\beta(p_b - z)}{1 - D^{-1}(1-\delta)(1-\beta f_b)} = \frac{\beta}{1-\beta} \frac{\kappa}{q_b} + U_b.$$

This completes the steady-state solution for the large member of the currency union b .

Using this solution we can next compute the steady-state of the small member of the currency union a by repeating the steps above. As before we normalize the population size to 1, so that all variables can be interpreted in per capita form. (Of course, we take into account

that $\frac{l_a}{l_b} \rightarrow 0$ in the equations for international trade and bond holdings.)

We impose three additional normalization. First, net debt is zero in steady-state $B_a = 0$. Second, relative Pareto weights are proportional to population size,

$$\Omega_{a,b} = \bar{\Omega} \frac{l_a}{l_b}.$$

Third, we solve for $\bar{\Omega}$ such that the relative price of home and foreign goods is 1. In our setup this yields $\bar{\Omega} = 1$.

C.9. Model with geographic mobility

We next describe the labor market in the model with geographic mobility. At the end of period t , employed workers transition into unemployment in their same industry at rate $\delta_t - \lambda_t$. Both unemployed and employed workers receive an industry reallocation shock at exogenous rate $\lambda_{a,t}^I$ and an area reallocation shock at exogenous rate $\lambda_{a,t}^A$, where $\lambda_t = \lambda_{a,t}^I + \lambda_{a,t}^A$. An industry reallocation shock consists of an immediate job separation if previously employed, and a draw of I idiosyncratic taste shocks $\{\varepsilon_j\}_{j=1}^I$ from a distribution $F^I(\varepsilon)$. These taste shocks enter additively into the worker's value function for searching in each sector $j = 1, \dots, I$ in the worker's initial area a . An area reallocation shock has two parts. First, the worker draws A fixed taste parameters ψ_a and A idiosyncratic shocks $\{\varepsilon_b\}_{b=1}^A$ from a distribution $F^A(\varepsilon)$, which enter additively into the worker's value function for searching in area $b = 1, \dots, A$. After choosing a location, she then draws idiosyncratic industry taste shocks $\{\varepsilon_j\}_{j=1}^I$ to determine her new industry. We parameterize $F^I(\varepsilon)$ and $F^A(\varepsilon)$ as Type I EV($-\rho^h \tilde{\gamma}, \rho^h$), where $h \in \{I, A\}$ and $\tilde{\gamma}$ is Euler's constant.

Reallocation shock frequencies $\lambda_{a,t}^A$ scale linearly with area size. In our calibration, we chose the fixed parameters $\{\psi_a\}_{a=1}^A$ such that workers are indifferent between moving in the symmetric steady-state. (Otherwise, workers may prefer the small area because of the greater likelihood of getting a taste shock.)

We denote the transition probability from area a to area b conditional on an area reallocation shock by $\pi_{ab,i,t}^A$ for a worker starting in industry i . Upon entering a new area b , the worker

chooses industry j with probability $\pi_{b,j,t}^I$. Area reallocation shocks are then also independent of the worker's employment status, initial area and initial industry, $\pi_{ab,i,t}^A = \pi_{cb,j,t}^A = \pi_{b,t}^A$. We have three laws of motion for the evolution of job seekers, employment, and unemployment:

$$x_{a,i,t} = \delta_{t-1}e_{a,i,t-1} + u_{a,i,t-1} - \lambda_{t-1}l_{a,i,t-1} + \pi_{a,i,t-1}^I \left[\lambda_{a,t-1}^I l_{a,t-1} + \pi_{a,t-1}^A \sum_{b=1}^A \lambda_{b,t-1}^A l_{b,t-1} \right],$$

$$e_{a,i,t} = (1 - \delta_{t-1})e_{a,i,t-1} + f_{a,i,t}x_{a,i,t},$$

$$u_{a,i,t} = (1 - f_{a,i,t})x_{a,i,t}.$$

The Bellman equations and free entry condition summarizing the labor market block of the model are now:

$$J_{a,i,t} = (p_{a,i,t} - w_{a,i,t}) + (1 - \delta_t)m_{a,t,t+1}J_{a,i,t+1},$$

$$W_{a,i,t} = w_{a,i,t} + m_{a,t,t+1} \left\{ [(1 - \delta_t) + (\delta_t - \lambda_t) f_{a,i,t+1}] W_{a,i,t+1} + (\delta_t - \lambda_t) (1 - f_{a,i,t+1}) U_{a,i,t+1} \right. \\ \left. + \lambda_{a,t}^I \left(\mathbf{E} \max_j \{ (1 - f_{a,j,t+1}) U_{a,j,t+1} + f_{a,j,t+1} W_{a,j,t+1} + \psi_{aj} + \varepsilon_{jt} \} \right) \right. \\ \left. + \lambda_{a,t}^A \left(\mathbf{E} \max_b \left\{ \mathbf{E} \max_j [(1 - f_{b,j,t+1}) U_{b,j,t+1} + f_{b,j,t+1} W_{b,j,t+1} + \psi_{bj} + \varepsilon_{jt}] + \psi_b + \varepsilon_{bt} \right\} \right) \right\},$$

$$U_{a,i,t} = z + m_{a,t,t+1} \left\{ (1 - \lambda_t) [f_{a,i,t+1} W_{a,i,t+1} + (1 - f_{a,i,t+1}) U_{a,i,t+1}] \right. \\ \left. + \lambda_{a,t}^I \left(\mathbf{E} \max_j \{ (1 - f_{a,j,t+1}) U_{a,j,t+1} + f_{a,j,t+1} W_{a,j,t+1} + \psi_{aj} + \varepsilon_{jt} \} \right) \right. \\ \left. + \lambda_{a,t}^A \left(\mathbf{E} \max_b \left\{ \mathbf{E} \max_j [(1 - f_{b,j,t+1}) U_{b,j,t+1} + f_{b,j,t+1} W_{b,j,t+1} + \psi_{bj} + \varepsilon_{jt}] + \psi_b + \varepsilon_{bt} \right\} \right) \right\},$$

$$\kappa = q_{a,i,t} J_{a,i,t}.$$

We also assume that the taste shocks $\varepsilon_{a,j,t}^A$ come from type 1 EV($-\rho^I \tilde{\gamma}, \rho^A$) distribution,

$$\varepsilon \sim \exp \left(-\frac{\varepsilon + \rho^A \tilde{\gamma}}{\rho^A} \right) \exp \left[-\exp \left(-\frac{\varepsilon + \rho^A \tilde{\gamma}}{\rho^A} \right) \right]. \quad (\text{D.8})$$

Following the same steps as for the industry taste shocks, we get

$$\pi_{b,t}^A = \frac{\exp \left(\frac{X_{b,t+1} + \psi_b}{\rho^A} \right)}{\sum_{a=1}^A \exp \left(\frac{X_{a,t+1} + \psi_a}{\rho^A} \right)}, \quad (\text{D.9})$$

where $\pi_{b,t}^A$ denotes the probability of moving to area b conditional on receiving a λ^A shock, and

$X_{b,t+1} = \mathbf{E} \max_j [X_{b,j,t+1} + \psi_{bj} + \varepsilon_{jt}]$ is the value of searching (net of the taste shock) in area b .

We calibrate the geographical mobility parameters as follows. We set $\lambda_a^A = 0.004$ in the small area to match the 2.5% average annual migration rate in [Kaplan and Schulhofer-Wohl \(2017\)](#). In a steady-state the migration rate must scale inversely with population. Since the large area is infinitely larger than the small area, we set $\lambda_b^A = 0$. However, note that there is still migration from large to small, only that it is finite from the perspective of the small area and infinitesimal from the perspective of the large area. We adjust the incidence of (non-migration) separations, $\delta - \lambda_a^A = 0.062$, so that total separations are unchanged relative to our baseline model, $\delta = 0.066$.

We adjust our calibration procedure for λ^I to account for migration. In steady state, there are $(\delta - \lambda_a^A)e$ new unemployed each period from the current location. The probability of switching industries conditional on a λ_a^I shock is approximately $(I - 1)/I$. Of the newly unemployed who remain in their same geographic area throughout their unemployment spell,

$$\frac{(\delta - \lambda_a^A - \lambda_a^I \frac{I-1}{I}) ef [1 + (1-f)(1 - \lambda_a^A - \lambda_a^I \frac{I-1}{I}) + (1-f)^2 (1 - \lambda_a^A - \lambda_a^I \frac{I-1}{I})^2 + \dots]}{(\delta - \lambda_a^A) ef [1 + (1-f)(1 - \lambda_a^A) + (1-f)^2 (1 - \lambda_a^A)^2 + \dots]} = \frac{\frac{(\delta - \lambda_a^A - \lambda_a^I \frac{I-1}{I})}{1 - (1-f)(1 - \lambda_a^A - \lambda_a^I \frac{I-1}{I})}}{\frac{(\delta - \lambda_a^A)}{1 - (1-f)(1 - \lambda_a^A)}} \quad (\text{D.10})$$

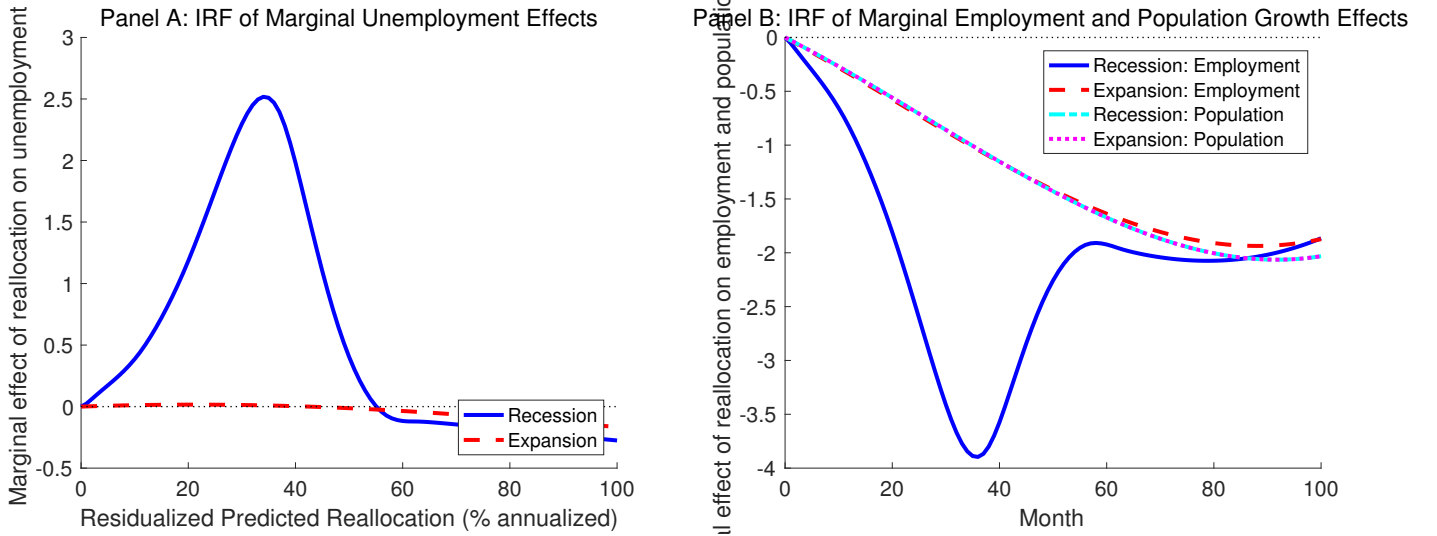
will not switch industries at least once before regaining employment. Thus, the share c of workers who go through an unemployment spell and cross industries is:

$$c = 1 - \frac{\frac{(\delta - \lambda_a^A - \lambda_a^I \frac{I-1}{I})}{1 - (1-f)(1 - \lambda_a^A - \lambda_a^I \frac{I-1}{I})}}{\frac{(\delta - \lambda_a^A)}{1 - (1-f)(1 - \lambda_a^A)}},$$

which given the values of δ , λ_a^A , and f described above, can be solved for λ_a^I . We use the CPS matched basic monthly files, described in appendix D, to find a c of 0.6 across NAICS 3 digit industries between 1994 and 2014, implying $\lambda_a^I \frac{I-1}{I} = 0.037$. Symmetric industry reallocation in steady-state implies $\lambda = \lambda_a^I + \lambda_a^A = \lambda_b^I = 0.041$.

The only estimate of ρ^A of which we are aware comes from [Kennan and Walker \(2011\)](#). Translated into our setting, these authors find a value of ρ^A of about 1.1. Since this is close to our estimate of across-industry reallocation frictions $\rho^I = 0.95$, we set $\rho^A = 0.95$ for symmetry.

Figure 8 – Model Impulse Response Function and Marginal Effect



Notes: Panels A and B displays the marginal effect of reallocation in recessions and expansions based on on a regression of the change in unemployment on local reallocation instrumented by predicted reallocation and controlling for predicted growth.

Solving for the steady-state is analogous, except for the following equations for the small area,

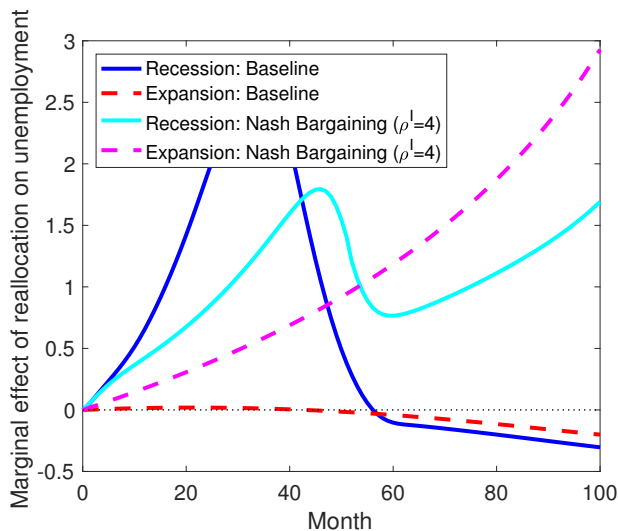
$$\pi_{a,j}^A = \frac{1}{2}$$

We conduct the same experiment in the model with geographical mobility as before. Figure 8 shows the implies marginal effects of reallocation on unemployment, employment, and population. The marginal effect on unemployment is similar to our baseline model. With migration it peaks at 2.52 compared to 2.77 in the baseline. Migration does amplify the marginal effects on employment and population. At its peak, approximately 26% of the employment response is accounted for by migration.

C.10. Model with Nash Bargaining

In model without downward wage rigidity in section 5 we used the same idiosyncratic noise parameter as in our baseline, $\rho^I = 0.95$. This is because raising ρ^I to hit the peak marginal unemployment effect resulted in much wider dispersion in the productivity paths, causing negative job surplus in the contracting sector. In figure 9 we instead report the comparison with a higher $\rho^I = 4$, such that the surplus remains positive in all sectors.

Figure 9 – Model Impulse Response Function and Marginal Effect



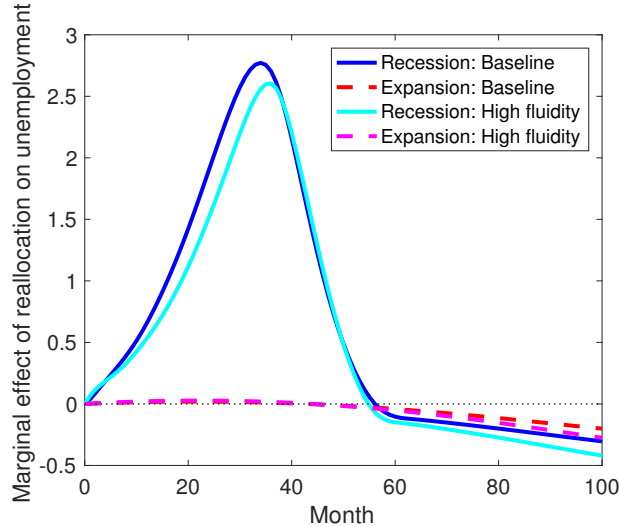
Notes: The figure displays the marginal effect of reallocation in recessions and expansions based on a regression of the change in unemployment on local reallocation instrumented by predicted reallocation and controlling for predicted growth. In the Nash Bargaining calibration, the reallocation noise parameter equals $\rho^I = 4$ to raise the peak unemployment effect closer to the data.

In this case, the marginal effects of reallocation on unemployment under Nash Bargaining are too large in expansions and too small in recessions. Thus, this model is inconsistent with the asymmetry we found in table 5. Furthermore, the marginal effects increase with the horizon, whereas in figure 3 we estimate a hump-shaped impulse response. We conclude that the model with downward-wage rigidity provides a better fit to the data. It outperforms the Nash Bargaining in its ability to match the peak marginal effect of reallocation on unemployment in recessions, and it provides a better match of the asymmetry and the dynamics.

C.11. Model with higher fluidity

We investigate whether higher fluidity in the spirit of [Davis and Haltiwanger \(2014\)](#) can improve unemployment outcomes from sectoral labor reallocation. Relative to our baseline calibration we raise the rate of unemployment to employment transitions and the rate of employment to unemployment transitions by a factor of 1.25. We leave all other parameters as in the baseline. Figure 10 displays the implied marginal effects of reallocation on unemployment in the high-fluidity calibration versus the baseline. We find that higher fluidity attenuates the negative effects of reallocation on unemployment.

Figure 10 – Model Impulse Response Function and Marginal Effect



Notes: The figure displays the marginal effect of reallocation in recessions and expansions based on a regression of the change in unemployment on local reallocation instrumented by predicted reallocation and controlling for predicted growth. In the high fluidity calibration, the transition rates from employment to unemployment and from unemployment to employment are 25% higher than in the baseline.

D. Wage Compression Over the Cycle

Table E.1 tests for the asymmetry of wage compression during recessions and expansions using national hourly wages by industry from the CPS and QCEW employment share changes during recession-recoveries and expansions. The table reports regressions where each observation is a national NAICS 2, SIC 2, or NAICS 3 digit industry during a national recession or expansion episode. The dependent variable is the change in the industry wage premium during a recession or expansion, described further below. By construction, the dependent variable has essentially zero mean across industries in a given time period, and the changes in industry shares also have essentially zero mean within a time period. We therefore omit time fixed effects from the regressions for parsimony. We weight the SIC 2/NAICS 3 digit regressions by employment share because smaller industries have greater measurement error in the industry wage premia. The regressors include the growth rate of the employment share in the industry during the expansion or recession-recovery containing the recession, and the growth rate interacted with the state of the business cycle.

Industries with rising employment shares have rising wage differentials during expansions.

Table E.1 – Recession Wage Compression in the Data

	Dep. var.: change in industry wage premium	
	NAICS 2	SIC 2/NAICS 3
	(1)	(2)
Right hand side variables:		
Share change growth rate $\left(\frac{12}{j} \frac{2\Delta s_{i,t}}{s_{i,t}+s_{i,t-T}}\right)$	0.39 ⁺ (0.19)	0.35* (0.15)
Recession X $\frac{12}{j} \frac{2\Delta s_{i,t}}{s_{i,t}+s_{i,t-T}}$	-0.43* (0.20)	-0.35* (0.17)
Employment share weighted	No	Yes
Industry clusters	17	143
Observations	102	492

Notes: The dependent variable is the change in the industry wage premium over the recession or expansion episode. The wage premium is a centered twelve month moving average of the industry fixed effect in a regression in the CPS ORG data of the log hourly wage on categorical variables for industry, race, 5 year age bin, gender, educational attainment, state, rural, and occupation. The variable $\frac{12}{j} \frac{2\Delta s_{i,t}}{s_{i,t}+s_{i,t-T}}$ is the annualized symmetric growth rate of the industry employment share during the expansion or the recession-recovery containing the recession in the QCEW data. Standard errors in parentheses and clustered by industry.

In contrast, there is no economically or statistically significant relationship between the change in the wage premium during a recession and industry share growth. The data reject equality of coefficients during expansions and recessions at the 5% level. Because realized reallocation and wage differentials may be jointly determined, we do not read causality into these results. Nonetheless, they provide evidence of wage compression between expanding and contracting industries during recessions but not during expansions, consistent with the mechanism in the model.

We now describe the construction of the dependent variable in table E.1. Raw earnings are usual hourly earnings from the Current Population Survey Outgoing Rotation Group (CPS ORG).⁸ For each month from 1979-2014, we construct crosswalk files between the CPS industry variable and NAICS 2 digit (1983-2014), SIC 2 digit (1979-February 1990) or NAICS 3 digit (March 1990-2014) industries.⁹ We restrict to individuals 16 years of age or older, employed and

⁸We extract the data using the CEPR uniform extracts: Center for Economic and Policy Research. 2015. CPS ORG Uniform Extracts, Version 2.0.1. Washington, DC. <http://ceprdata.org/cps-uniform-data-extracts/cps-outgoing-rotation-group/cps-org-data/>.

⁹Crosswalk files available from the authors upon request.

at work at least 15 hours in the CPS reference week, with an hourly wage of at least one-half the national minimum wage, and not a government employee. For each industry classification, we then regress the log of usual hourly earnings on an exhaustive set of industry categorical variables, state of residence categorical variables, 5 year age bins, educational attainment bins, race bins, an indicator for gender, an indicator for rural area, and categorical variables for occupation. To increase power, we estimate overlapping 5 month regressions allowing for the industry coefficients but not the other covariates to vary by month. We demean the coefficients on the industry categorical variables for the middle month and refer to the demeaned coefficients as the industry wage premia for that month. We then append the industry wage premia across months to create time series of the wage premia and take 13 month centered moving averages to remove seasonal effects and noise. The difference between the moving average of the premium in the first and last month of the episode is the dependent variable in table E.1.

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