Appendix to
Labor Market Conflict and the Decline of the Rust Belt
(For Online Publication Only)

A. Alternative Measures of Labor Conflict and Employment Growth

In section 2.5 of the main text we analyzed the relationship between major work stoppages, defined as stoppages involving at least 1,000 workers, and employment growth. In the following three subsections we conduct several robustness checks using alternative proxies for labor market conflict.

A.1. Alternative Size Thresholds for Work Stoppages

Table A.1 reports coefficient estimates of a regression of employment growth on work stoppages similar to those in Table A.3. Each row represents the results of an alternate specification. The dependent variable is the log employment change between 1950 and 2000 and the observations are state-industry pairs. The other independent variables are identical to specifications (1) - (4) in Table A.3.

As a frame of reference, the first row of Table A.1 reproduces the benchmark results of Table A.3, where the independent variable of interest is work stoppages affecting 1,000 or more workers. The second row uses work stoppages affecting 2,000 workers or more, and keeps all else the same. Coefficients on work stoppages are larger in this case, and still everywhere statistically significant. The third and fourth rows consider lower thresholds on work stoppages, in particular 500 or more workers and 0 or more workers. These coefficients are smaller in magnitude but still statistically significant. In terms of economic magnitude, these regressions confirm the strong relationship between work stoppages and employment growth at the industry-state level. The negative relationship between the threshold number of workers involved and the magnitude of the coefficient is largely

Table A.1: Robustness of State-Industry Regressions

Alternative Regression	Regression Specification (1)	(2)	(3)	(4)
Work Stoppages/Year, 1,000+ workers	-0.41***	-0.30***	-0.29***	-0.27***
	(0.071)	(0.063)	(0.058)	(0.056)
Work Stoppages/Year, 2,000+ workers	-0.67***	-0.50***	-0.48***	-0.44***
	(0.12)	(0.11)	(0.10)	(0.092)
Work Stoppages/Year, 500+ workers	-0.17***	-0.12***	-0.11***	-0.10***
	(0.046)	(0.038)	(0.035)	(0.036)
Work Stoppages/Year, 0+ workers	-0.019**	-0.012*	-0.011**	-0.0080*
	(0.0090)	(0.0062)	(0.0055)	(0.0048)
Percent of Workers in Stoppages	-0.13***	-0.11***	-0.090***	-0.068***
	(0.020)	(0.017)	(0.020)	(0.021)
Sample Restriction: Only Manufacturing	-0.39***	-0.23***	-0.22***	-0.22***
	(0.073)	(0.059)	(0.054)	(0.056)

Note: The dependent variable in all regressions is log employment growth from 1950 to 2000. All else as in Table 2 except where indicated. Coefficients on all other independent variables are omitted for brevity. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

driven by the fact that the number of work stoppages increases as the threshold declines. In the case of work stoppages affecting any positive number of workers, the standard deviation rises to 3.9 from 0.9 in the benchmark. Thus, moving from two standard deviations below the mean to two standard deviations above will lead to a 13 percent decline in employment. This is comparable in magnitude to the estimate in the benchmark regression specification. We conclude that our results are not artefacts of the exact thresholds for workers affected by work stoppages.

The fifth row takes as its main independent variable the number of workers involved in work stoppages from 1958 to 1977 divided by total employment (summing over all the years) over this period. In other words, the dependent variable is the percent of workers involved in a work stoppage. Thus, instead of choosing a particular cutoff for workers involved, this alternative variable takes a more continuous measure of conflict. This independent variable also shows up with a large estimated coefficient that is statistically significant in all four specifications. Our results are also robust to this more continuous measure of work stoppages.

In the final two rows of Table A.1 we revert to the independent variable from our benchmark specification (stoppages affecting at least 1,000 workers), but we change the dependent variable and sample selection. The final row of the table is the same regression as the others but restricts the sample to only manufacturing industries. The estimated coefficient is still large and statistical significant. We conclude that an earlier timeframe for employment growth and restriction to just manufacturing still leave our conclusions from Section 2 intact.

A.2. Unionization Rates, 1973 to 1980

Next, we explore if the relationship between labor conflict and employment growth is robust to using a different proxy: the unionization rate. Unions have historically been related to labor conflict, though as a comparison of Tables 1 and A.2 reveals, unionization rates are not perfectly correlated with work stoppages. Adversarial labor-management relations and hold-up problems, for instance, can arise even in the absence of strikes.

Table A.2: Unionization Rates by Region and Sector

	Fraction of Unionized Workers (Percent)		
	Manufacturing	Services	Overall
Rust Belt	48.1	22.5	30.9
Rest of Country	28.4	14.4	18.1

A limitation of our unionization measure is that data at the individual level on union participation is only available in the CPS starting in 1973, and the data are only comparable up to 1980. As in the measure of work stoppages, we aggregate the data to the state-industry level, to be at a comparable level of aggregation as our other variables. The CPS reports state-data in groups until 1978. We allocate workers to state within each group according to the state population shares in later years, where data is reported for each individual state. Note that our data are highly correlated with CPS unionization data from 1983 to 1992, which tend to be more widely used.

Table A.3 reports the results of four regressions of log employment growth from 1950 to 2000 on unionization and the same set of other correlates as Table A.3. In particular, all observations are again at the state-industry level, and all regressions include an industry fixed effect. The first column shows that unionization rates are highly negatively related

Table A.3: Unionization Rates and Employment Growth

Independent Variables	Dep. Var: Log Employment Growth 1950-2000 (1)	(2)	(3)	(4)
Unionization Rate	-0.74***	-0.56***	-0.34***	-0.30***
	(0.076)	(0.077)	(0.075)	(0.072)
Percent College Grad, 1950	0.076	0.061	-0.022	-0.031
	(0.094)	(0.093)	(0.086)	(0.074)
Log State Population, 1950		-0.071***	-0.12***	
		(0.014)	(0.015)	
State Mfg Employent Share, 1950		-1.83***	-0.85***	
		(0.12)	(0.15)	
State Empl. Herfindahl Index, 1950		-2.41***	-1.24***	
		(0.37)	(0.36)	
State Average Temperature			0.014***	
			(0.0027)	
State Std. Dev. Temperature			-0.060***	
			(0.0070)	
State Average Precipitation			-0.014***	
			(0.0013)	
Constant	-1.49***	-0.83***	-0.39	-1.45***
	(0.096)	(0.10)	(0.25)	(0.13)
Observations	4,691	4,691	4,628	4,691
R^2	0.611	0.637	0.694	0.747
Industry Fixed Effects	Y	Y	Y	Y
State Fixed Effects	N	N	N	Y

Note: The dependent variable in all regressions is log employment growth from 1950 to 2000. Observations are at the state-industry level. The first independent variable is unionization rate over the period 1973 to 1980, and the second is the percent of workers in the state-industry in 1950 that are college graduates. All other independent variables are measured at the state level in 1950. Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

to employment growth. The coefficient on unionization is -0.74, meaning that moving the unionization rate from zero to one hundred percent is associated with 74 log points lower employment growth compared to the same industry in other states. The percent college graduate is again positive but insignificant. Adding controls for population, manufacturing employment share and the employment concentration paints a similar picture, and again leaves the coefficient on unionization large, negative, and statistically significant, at -0.56. Adding controls for climate variables lowers the coefficient on unionization to

-0.34, and adding a state fixed effect leads to a unionization coefficient estimate of -0.30. Still, estimated coefficients on unionization are statistically significant at the one-percent level and economically large. We conclude that using unionization to proxy for work stoppages leads to a very similar picture as using work stoppages.

A.3. Strikes from 1927 to 1934

While the results reported in Tables 2 and A.3 are certainly consistent with our theory that labor conflict reduced employment growth, an alternative hypothesis is that the employment decline caused the conflict. In particular, one could worry that once workers realized that their firms or industries were declining, they responded by unionizing or striking.

To address this potential reverse causality story, we draw on data on labor conflict that long pre-dated the postwar employment outcomes that are the dependent variables in Tables 2 and A.3. In particular, we draw on strikes data collected by the BLS in the 1920s and 1930s. The earliest data we found at the state-industry level were from 1927 to 1936, though we focus on the period 1927 to 1934, since this pre-dated the Wagner Act of 1935, which greatly increased the ability of workers nationwide to form collective bargaining arrangements. These early measures of conflict are likely related to the deep-seated distrust between workers and firms that began in this period, but is unlikely to be caused by any employment outcome starting two decades later.

Note that these data have some clear limitations. In particular, they are the two-digit industry level, which makes the mapping to the three-digit industries in the more recent data somewhat crude. Moreover, the data are only reported in states that had at least twenty five total strikes over this period. Thus, we are forced to drop states with few strikes, and this amounts to dropping around half the states and 30 percent of the total population represented by the data. These limitations make it harder to find associations between our dependent variables and our measure of strikes from 1927 and 1934.

Table A.4 presents the results of regressions of log employment growth from 1950 to 2000 on strikes from 1927 to 1934 and the same independent variable as in Tables 2 and A.3. Using the same set of regression controls as above, strikes from 1927 to 1934 are significantly negatively related to employment growth from 1950 to 2000. With just the percent college graduate (and the industry fixed effects) as controls, the coefficient on strikes is -0.040. Adding the state controls for initial population and economic structure lower the coefficient to -0.019, and adding state climate controls lowers the strikes estimate to -0.018. Adding state fixed effects further lowers the strikes coefficient to -0.012, though in

Table A.4: Strikes Per Year from 1927 to 1934 and Postwar Employment Growth

Independent Vars	(1)	(2)	(3)	(4)
	Dep. Var: Log Employment Growth 1950-2000			
Strikes 1927-1934	-0.040***	-0.019***	-0.018***	-0.012***
	(0.0045)	(0.0040)	(0.0040)	(0.0039)
Percent College Grad, 1950	0.087	0.10	0.033	0.024
	(0.13)	(0.12)	(0.12)	(0.11)
Log State Population, 1950		-0.093***	-0.096***	
		(0.020)	(0.023)	
State Mfg Employent Share, 1950		-2.68***	-2.05***	
		(0.14)	(0.18)	
State Empl. Herfindahl Index, 1950		3.85***	4.51***	
		(0.68)	(0.72)	
State Average Temperature			-0.0050	
			(0.0033)	
State Std. Dev. Temperature			-0.057***	
			(0.0082)	
State Average Precipitation			-0.012***	
			(0.0020)	
Constant	-1.54***	-0.70***	0.72**	-1.33***
	(0.16)	(0.18)	(0.33)	(0.19)
Observations	2,834	2,834	2,834	2,834
R^2	0.663	0.712	0.721	0.745
Industry Fixed Effects	Y	Y	Y	Y
State Fixed Effects	N	N	N	Y

Note: The dependent variable in all regressions is log employment growth from 1950 to 2000. Observations are at the state-industry level. The first independent variable is the average number of strikes from 1927 to 1934, and the second is the percent of workers in the state-industry in 1950 that are college graduates. All other independent variables are measured at the state level in 1950. Robust standard errors are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

all cases strikes are statistically significant at the one-percent level.

How does the economic significance of strikes from 1927 to 1934 relate to that of the postwar work stoppages variable? The standard deviation of strikes from 1927 to 1934 is 32, so moving from one standard deviation below the mean to one standard deviation above is associated – in regression (4) – with around 77 log points lower employment growth. This suggest an economically large effect of conflict on employment outcomes, as in Tables 2 and A.3.

Overall, the results of Table A.4 provide evidence against a reverse-causality story running from industry decline to conflict. Instead, the results suggest that the causality runs from strikes to employment growth, which corroborates the thesis of this paper.

B. Section 3 Appendix

B.1. Derivation of Strike Probability

$$\begin{aligned}
\tilde{F}\left(R_t\left(i\right)\right) \equiv \Pr\left(R_t\left(i\right) > \tilde{R}_t\left(i\right)\right) &= \Pr\left(\frac{\ln\left(\frac{R_t(i)\sigma}{X_t\left(1-(1-\phi)(1-\kappa)^{\sigma-1}\right)}\left(\frac{\sigma}{\sigma-1}\frac{w_t}{P_t}\frac{1}{z_t(i)}\right)\right)}{\sigma-1} > \varepsilon_t(i)\right) \\
&= \frac{\frac{\ln\left(\frac{R_t(i)\sigma}{X_t\left(1-(1-\phi)(1-\kappa)^{\sigma-1}\right)}\left(\frac{\sigma}{\sigma-1}\frac{w_t}{P_t}\frac{1}{z_t(i)}\right)\right)}{\sigma-1} - \underline{\varepsilon}}{\overline{\varepsilon}-\underline{\varepsilon}} \\
&= \frac{\mathcal{R}^{-1}\left(R_t(i)\right) - \underline{\varepsilon}}{\overline{\varepsilon}-\underline{\varepsilon}}. \qquad (24)
\end{aligned}$$

B.2. Proofs of Propositions in Section 3

Proof of Proposition 1.

$$\begin{aligned}
\frac{\partial R_t^*(i)}{\partial \phi} &= \underbrace{(1-\kappa)^{\sigma-1}\left(1 + \frac{(1-\kappa)^{\sigma-1}}{\left(1-(1-\phi)(1-\kappa)^{\sigma-1}\right)^2}\right)}_{>0} \\
&\quad \times \underbrace{\frac{X_t}{\sigma}\left(\frac{\sigma-1}{\sigma}\frac{P_t}{w_t}z_t e^{\bar{\varepsilon}}\right)^{\sigma-1}}_{>0}\underbrace{e^{-\frac{1-(1-\kappa)^{\sigma-1}}{1-(1-\phi)(1-\kappa)^{\sigma-1}}}}_{>0} \\
&> 0 \quad \forall \phi \in (0,1) \text{ and } \sigma > 1 \\
\frac{\partial \tilde{F}\left(R_t^*\left(i\right)\right)}{\partial \phi} &= \frac{1-(1-\kappa)^{\sigma-1}}{\left(1-(1-\phi)(1-\kappa)^{\sigma-1}\right)}\frac{(1-\kappa)^{\sigma-1}}{2\bar{\varepsilon}(\sigma-1)} \\
&> 0 \quad \forall \phi \in (0,1) \text{ and } \sigma > 1
\end{aligned}$$

Q.E.D.

Proof of Proposition 2.

The proof proceeds in two parts.

1. Let i denote a firm in the Rust Belt and j a firm elsewhere. According to equation (15) we have:

$$\begin{aligned}
E[x_t(j)] &= E\left[\left(s\pi_t(j)\frac{\mathcal{Z}_t^{\sigma-1}}{\alpha z_t(j)^{\sigma-1}}\right)^{\frac{1}{\gamma}}\right] \\
&= \left(\frac{s\mathcal{Z}_t^{\sigma-1}}{\alpha}\right)^{\frac{1}{\gamma}} E\left[\left(\frac{\pi_t(j)}{z_t(j)^{\sigma-1}}\right)^{\frac{1}{\gamma}}\right] \\
&= \left[\frac{s\mathcal{Z}_t^{\sigma-1}}{\alpha}\left(\frac{\sigma-1}{\sigma}\frac{P_t}{w_t}\right)^{\sigma-1}\frac{X_t}{\sigma}\right]^{\frac{1}{\gamma}} E\left[e^{\varepsilon_t(j)\frac{\sigma-1}{\gamma}}\right] \\
&= \left[\frac{s\mathcal{Z}_t^{\sigma-1}}{\alpha}\left(\frac{\sigma-1}{\sigma}\frac{P_t}{w_t}\right)^{\sigma-1}\frac{X_t}{\sigma}\right]^{\frac{1}{\gamma}} \frac{\gamma}{2\bar{\varepsilon}(\sigma-1)}\left(e^{\bar{\varepsilon}\frac{\sigma-1}{\gamma}} - e^{-\bar{\varepsilon}\frac{\sigma-1}{\gamma}}\right)
\end{aligned}$$

and

$$\begin{aligned}
E[x_t(i)] =&(1-\tilde{F}(R_t^*(i)))E\left[\left(s(\pi_t(i)-R_t^*(i))\frac{\mathcal{Z}_t^{\sigma-1}}{\alpha z_t(i)^{\sigma-1}}\right)^{\frac{1}{\gamma}}\right] \\
&+\tilde{F}(R_t^*(i))E\left[\left(s(1-\phi)(1-\kappa)^{\sigma-1}\pi_t(i)\frac{\mathcal{Z}_t^{\sigma-1}}{\alpha z_t(i)^{\sigma-1}}\right)^{\frac{1}{\gamma}}\right] \\
<&(1-\tilde{F}(R_t^*(i)))E\left[\left(s\pi_t(i)\frac{\mathcal{Z}_t^{\sigma-1}}{\alpha z_t(i)^{\sigma-1}}\right)^{\frac{1}{\gamma}}\right] \\
&+\tilde{F}(R_t^*(i))E\left[\left(s\pi_t(i)\frac{\mathcal{Z}_t^{\sigma-1}}{\alpha z_t(i)^{\sigma-1}}\right)^{\frac{1}{\gamma}}\right] \\
=&E\left[\left(s\pi_t(i)\frac{\mathcal{Z}_t^{\sigma-1}}{\alpha z_t(i)^{\sigma-1}}\right)^{\frac{1}{\gamma}}\right] \\
=&\left[\frac{s\mathcal{Z}_t^{\sigma-1}}{\alpha}\left(\frac{\sigma-1}{\sigma}\frac{P_t}{w_t}\right)^{\sigma-1}\frac{X_t}{\sigma}\right]^{\frac{1}{\gamma}} \frac{\gamma}{2\bar{\varepsilon}(\sigma-1)}\left(e^{\bar{\varepsilon}\frac{\sigma-1}{\gamma}} - e^{-\bar{\varepsilon}\frac{\sigma-1}{\gamma}}\right) \\
=&E[x_t(j)]
\end{aligned}$$

2. Let θ^R and θ^S denote the employment shares of the Rust Belt and the Rest-of-the-

Country, respectively. The optimal labor input of a firm located outside the Rust Belt or of a Rust Belt firm not subject to a strike is given by

$$n_t(i) = \left(\frac{\sigma - 1}{\sigma}\frac{P_t}{w_t}\right)^{\sigma} \left(e^{\varepsilon_t(i)} z_t(i)\right)^{\sigma-1} \frac{X_t}{P_t}. \tag{25}$$

A Rust Belt firm subject to a strike hires

$$\underline{n}_t(i) = \left(\frac{\sigma - 1}{\sigma}\frac{P_t}{w_t}\right)^{\sigma} \left((1-\kappa)e^{\varepsilon_t(i)} z_t(i)\right)^{\sigma-1} \frac{X_t}{P_t} \tag{26}$$

workers. Using (25) and (26) we can characterize θ^S and θ^R:

$$\begin{aligned}
E[\theta_t^S] &\equiv E\left[\int_\lambda^1 n_t(j)dj\right] \\
&= \int_\lambda^1 E\left[n_t(j)\right] dj \\
&= \int_\lambda^1 \left(\frac{\sigma-1}{\sigma}\frac{P_t}{w_t}\right)^{\sigma} \frac{X_t}{P_t}\frac{e^{\bar{\varepsilon}(\sigma-1)} - e^{-\bar{\varepsilon}(\sigma-1)}}{2\bar{\varepsilon}(\sigma-1)} z_t(j)dj \\
&= \left(\frac{\sigma-1}{\sigma}\frac{P_t}{w_t}\right)^{\sigma} \frac{X_t}{P_t}\frac{e^{\bar{\varepsilon}(\sigma-1)} - e^{-\bar{\varepsilon}(\sigma-1)}}{2\bar{\varepsilon}(\sigma-1)} \int_\lambda^1 z_t(j)dj
\end{aligned}$$

and

$$\begin{aligned}
E[\theta_t^R] &\equiv E\left[\int_0^\lambda n_t(i)di\right] \\
&= \int_0^\lambda E\left[n_t(i)\right] di \\
&= \int_0^\lambda \left[\int_{e^{-\bar{\varepsilon}}}^{e^{\tilde{\varepsilon}}} \underline{n}_t(i)de^{\varepsilon_t(i)} + \int_{e^{\tilde{\varepsilon}}}^{e^{\bar{\varepsilon}}} n_t(i)de^{\varepsilon_t(i)}\right] di \\
&= \left(\frac{\sigma-1}{\sigma}\frac{P_t}{w_t}\right)^{\sigma} \frac{X_t}{P_t}\left[(1-\kappa)^{\sigma-1}\frac{e^{\tilde{\varepsilon}(\sigma-1)} - e^{-\bar{\varepsilon}(\sigma-1)}}{2\bar{\varepsilon}(\sigma-1)} + \frac{e^{\bar{\varepsilon}(\sigma-1)} - e^{\tilde{\varepsilon}(\sigma-1)}}{2\bar{\varepsilon}(\sigma-1)}\right] \int_0^\lambda z_t(i)di,
\end{aligned}$$

where $\tilde{\varepsilon}$ denotes the realization of the productivity shock that makes the firm indifferent between accepting and rejecting the union's request $R_t^*(i)$. According to equation (61) this threshold value does not depend on the Rust Belt firms' productivity $z_t(i)$.

We can write the ratio of expected employment shares as

$$\frac{E[\theta_t^R]}{E[\theta_t^{RC}]} = M\frac{\int_0^\lambda z_t(i)di}{\int_\lambda^1 z_t(j)dj} \tag{27}$$

where

$$M \equiv \frac{(1-\kappa)^{\sigma-1}\frac{e^{\tilde{\varepsilon}(\sigma-1)}-e^{-\bar{\varepsilon}(\sigma-1)}}{2\bar{\varepsilon}(\sigma-1)}+\frac{e^{\bar{\varepsilon}(\sigma-1)}-e^{\tilde{\varepsilon}(\sigma-1)}}{2\bar{\varepsilon}(\sigma-1)}}{\frac{e^{\bar{\varepsilon}(\sigma-1)}-e^{-\bar{\varepsilon}(\sigma-1)}}{2\bar{\varepsilon}(\sigma-1)}}$$

is constant.

Based on Part 1. of the proof, we know that the expected growth rates of firm productivities are equalized across firms within the same region (Rust Belt and Rest-of-the-Country). Moreover, the expected growth rates for Rust Belt firms are uniformly lower. Therefore, the ratio of employment shares in (27) is decreasing over time, i.e. the employment share of Rust Belt firms is declining over time. Q.E.D.

B.3. Union Rent per Worker

In equilibrium, the union rent *per worker* does not depend on the firm's productivity $z_t(i)$. In section B.4 we show that each worker receives $\frac{\phi}{\sigma-1}$ in addition to the competitive wage w_t in the event of a strike.

What is less obvious is that $r_t \equiv \frac{R_t^*(i)}{E(n_t(i)|\varepsilon_t(i)\geq\tilde{\varepsilon})}$ is also equalized across firms.

Recall that according to equation (12), the optimal offer is

$$\begin{aligned} R_t^*(i) &= \left(1-(1-\phi)\left(1-\kappa\right)^{\sigma-1}\right)\frac{X_t}{\sigma}\left(\frac{\sigma-1}{\sigma}\frac{P_t}{w_t}z_t(i)e^{\bar{\varepsilon}}\right)^{\sigma-1} e^{-\dfrac{1-(1-\kappa)^{\sigma-1}}{1-(1-\phi)(1-\kappa)^{\sigma-1}}} \\ &\equiv \kappa_{t,R} z_t(i)^{\sigma-1} \end{aligned}$$

Using equation (25) and the notation $n_t(i,\varepsilon)$ to highlight the dependence of labor input on the realization of ε we can show that

$$\begin{aligned} E\left(n_t\left(i,\varepsilon\right)|\varepsilon_t(i)\geq\varepsilon^*\right) &= \int_{\tilde{\varepsilon}}^{\bar{\varepsilon}} n_t(i,\varepsilon)de^{\varepsilon_t(i)} \\ &= \left(\frac{\sigma-1}{\sigma}\frac{P_t}{w_t}\right)^{\sigma}\frac{X_t}{w_t}z_t(i)^{\sigma-1}\frac{e^{\bar{\varepsilon}(\sigma-1)}-e^{\tilde{\varepsilon}(\sigma-1)}}{2e^{\bar{\varepsilon}(\sigma-1)}} \\ &\equiv \kappa_{t,n} z_t(i)^{\sigma-1} \end{aligned}$$

It follows immediately that

$$\frac{R_t^*(i)}{E\left(n_t\left(i\right)|\varepsilon_t(i)\geq\tilde{\varepsilon}\right)} = \frac{\kappa_{t,R}}{\kappa_{t,n}}\frac{z_t(i)^{\sigma-1}}{z_t(i)^{\sigma-1}} = \frac{\kappa_{t,R}}{\kappa_{t,n}}$$

is equalized across firms indexed by i at time t.

B.4. Labor Markets and the Union

In addition to the competitive wage $w_t \equiv 1$, each worker employed by a Rust Belt firm $i \in [0, \lambda]$ receives a portion of the rents. If the union's take-it-or-leave-it offer is accepted, each worker gets an equal share of $R_t^*(i)$ given by (12). If the offer is rejected and a strike takes place, each worker receives an equal share of $\phi \underline{\pi}_t(i)$.

We assume that workers hired by a Rust Belt firm must be union members. This captures the "closed shop" nature of the labor contracts that were typical in Rust Belt industries. This arrangement implies that firms cannot bypass the union in order to recruit workers in the competitive labor market.

At the beginning of each period, workers decide whether to apply for a union job at one of the Rust Belt firms. These jobs are desirable since they pay the competitive wage plus a union rent. The size of this rent at a particular firm $i \in [0, \lambda]$ depends on whether a strike takes place, which workers do not know when they apply for a job. Instead, they decide whether to apply for a job at a particular firm based on the rent they can *expect* to earn.

Given firm i's productivity $z_t(i)$, prospective workers know that the union will propose the rent $R_t^*(i)$ according to equation (12) and that the probability of rejection, which leads to a strike at that firm is given by $\tilde{F}\left(R_t^*\left(i\right)\right)$ in equation (13).

It follows that, in expectation, a worker hired by a Rust Belt firm $i \in [0, \lambda]$ will be paid

$$\underbrace{1}_{\text{competitive wage}} + \left(1 - \tilde{F}\left(R_t^*\left(i\right)\right)\right) \underbrace{\frac{R_t^*(i)}{E\left(n_t\left(i\right)|\varepsilon_t(i) \geq \varepsilon^*\right)}}_{\textit{per capita} \text{ rent without strike}} + \tilde{F}\left(R_t^*\left(i\right)\right) \underbrace{\frac{\phi E\left(\pi_t(i)|\varepsilon_t(i) < \varepsilon^*\right)}{E\left(n_t\left(i\right)|\varepsilon_t(i) < \varepsilon^*\right)}}_{\textit{per capita} \text{ profit share with strike}},$$

where $\varepsilon^* = \mathcal{R}^{-1}\left(R_t^*\left(i\right)\right)$ is the threshold value of the transitory shock that solves

$$R_t^*(i) = \tilde{R}_t(i) \equiv \pi_t(i) - (1-\phi)\underline{\pi}_t(i). \tag{28}$$

The threshold $\tilde{R}_t(i)$ is a function of $\varepsilon_t(i)$ since it depends on realized profits in the agreement and non-agreement outcomes, $\pi_t\left(i\right)$ and $\underline{\pi}_t(i)$, respectively. Letting $\tilde{R}_t(i) \equiv g\left(\varepsilon_t(i)\right)$, one can show that:

$$g\left(\varepsilon_t(i)\right) = e^{\varepsilon_t(i)(\sigma-1)} \left(\frac{\sigma}{\sigma-1}\frac{w_t}{P_t}\frac{1}{z_t(i)}\right)^{1-\sigma} \frac{X_t}{\sigma}\left(1-(1-\phi)\left(1-\kappa\right)^{\sigma-1}\right). \tag{29}$$

According to equation (61), the probability of a strike does not depend on the firm's $z_t(i)$ and is constant over time. Let $\tilde{F}^* \equiv F\left(R_t^*\left(i\right)\right)$ denote this probability. Moreover, it is straightforward to show that $\frac{\phi E(\pi_t(i)|\varepsilon_t(i)<\varepsilon^*)}{E(n_t(i)|\varepsilon_t(i)<\varepsilon^*)} = \frac{\phi}{\sigma-1}$. Finally, using (9) and (12), it can be shown that $\frac{R^*_t(i)}{E(n_t(i)|\varepsilon_t(i)\geq\varepsilon^*)}$ does not depend on $z_t(i)$ either and remains constant over time. Let $r \equiv \frac{R^*_t(i)}{E(n_t(i)|\varepsilon_t(i)\geq\varepsilon^*)}$ be this per-worker rent in the no-strike case.

Clearly, arbitrage equalizes the *ex ante* value of a union job application across Rust Belt firms. The *ex ante* value is also constant over time, which has implications for the workers' decision to apply for union jobs. Since workers are not solving an intertemporal consumption-savings problem and have linear flow utility according to (1), the *ex ante* utility flow value of a job equals total expected, discounted income associated with that job.

The expected value of a Rust Belt job is given by:

$$E(v^R) = 1 + \left(1 - \tilde{F}^*\right) r + \tilde{F}^* \frac{\phi}{\sigma - 1} + E(D), \tag{30}$$

where $E(D)$ is the expected per capita dividend income. Every worker in this economy owns a single share of a fully diversified mutual fund and the firms' dividend payments are rebated to the funds' shareholders. In expectation, total dividends collected by the fund are given by:

$$\begin{aligned} E(D) =& (1-s)\Bigg(\int_0^\lambda \left(1 - \tilde{F}^*\right) \left(E\left(\pi_t(i)|\varepsilon_t(i) \geq \varepsilon^*\right) - R^*_t(i)\right) \\ & + \tilde{F}^*(1-\phi) E\left(\pi_t(i)|\varepsilon_t(i) < \varepsilon^*\right) di + \int_\lambda^1 E\left(\pi_t(i)\right) di \Bigg) \end{aligned} \tag{31}$$

Since the economy is populated by a unit measure of households, total dividends equal per capita dividends, in expectation, and each worker receives $E(D)$ in addition to income for labor services and union rents.

The expected value of a Rest-of-the-Country job is given by:

$$E(v^S) = 1 + E(D). \tag{32}$$

Since $E(v^R) > E(v^S)$, workers strictly prefer to be employed by a Rust Belt firm. Rust Belt jobs, however, are in scarce supply and workers need to decide whether to queue up at some firm $i \in [0, \lambda]$. If the queue at firm i is longer than the number of available jobs, workers are selected at random from the queue. *Ex post*, the number of workers hired by firm i depends on the realization of $\varepsilon_t(i)$ since, for given $z_t(i)$, firms with higher productivity shocks (1) hire more workers and (2) avoid the production time losses triggered by a strike.

If a worker queues up for a union job, but is not hired at time t, she can take a Rest-of-the-Country job immediately but suffers an exogenous utility cost $\bar{u}$.

Ex ante, the probability of being offered a job is given by:

$$\text{Pr (hired by } i) = \frac{(1-\tilde{F}^*)E\left(n_t(i)|\varepsilon_t(i) \geq \varepsilon^*\right) + \tilde{F}^* E\left(n_t(i)|\varepsilon_t(i) < \varepsilon^*\right)}{q_t(i)} = \frac{E\left(n_t\left(i\right)\right)}{q_t(i)}, \quad (33)$$

where $q_t(i)$ is the length of the queue at firm i and time t.

Workers queue at firm i if the expected payoff from doing so exceeds the payoff associated with taking a Rest-of-Country non-union job:

$$\frac{E\left(n_t\left(i\right)\right)}{q_t(i)} E(v^R) + \left(1 - \frac{E\left(n_t\left(i\right)\right)}{q_t(i)}\right)\left(E(v^S) - \bar{u}\right) \geq E(v^S) \quad (34)$$

Since the values of jobs don't depend on i, the probability of getting a union job is identical at all Rust Belt firms in equilibrium and is given by:

$$\frac{E\left(n_t\left(i\right)\right)}{q_t(i)} = 1 + \frac{E(v^R - v^S)}{\bar{u}} \quad (35)$$

This implies that $q_t(i)$ is proportional to the firm's productivity $z_t(i)$. The proportionality with respect to $z_t(i)$ is due to the constant probability of a strike across Rust Belt firms. In equilibrium, the constant *ex ante* probability of being offered a union job, conditional on queuing for one, is given by:

$$\frac{E\left(n_t\left(i\right)\right)}{q_t(i)} = \left(1 + \frac{E(v^R - v^S)}{\bar{u}}\right)^{-1} \leq 1. \quad (36)$$

C. Appendix for Quantitative Version of the Model

C.1. Derivations for Quantitative Version of the Model

In this subsection, we provide the full set of equations used in the quantitative version of the model.

Production Functions and Final Goods Sector. The *Foreign* counterparts of production functions (2) and (16) are:

$$Y_t^* = \left(\int_0^1 y_t^*(i)^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1}}$$
$$y^*(i) = \left(y^{*H}(i)^{\frac{\rho-1}{\rho}} + y^{*F}(i)^{\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{\rho-1}} .$$

There is free entry into the market for producing the final good. The representative producer in *Home* is a price-taker in both input and output markets and solves:

$$\max_{\{y(i)\}_{i\in[0,1]}} \Pi = PY - \int_0^1 p(i)y(i)di,$$

where perfect competition implies

$$P = \left(\int_0^1 p(i)^{1-\sigma} di \right)^{\frac{1}{1-\sigma}} .$$

Similarly, the representative *Foreign* firm solves:

$$\max_{\{y^*(i)\}_{i\in[0,1]}} \Pi^* = P^*Y^* - \int_0^1 p^*(i)y^*(i)di,$$

where

$$P^* = \left(\int_0^1 p^*(i)^{1-\sigma} di \right)^{\frac{1}{1-\sigma}} .$$

Firm Profit Maximization. Firms maximize total expected profits:

$$E\left(\Pi^H(i)\right) = E\left(\pi^H(i)\right) + E\left(\pi^{*H}(i)\right),$$

where

$$E\left(\pi^H(i)\right) = \max_{n^H(i)} E\left(p^H(i)y^H(i)\right) - wn^H(i), \quad (37)$$
$$E\left(\pi^{*H}(i)\right) = \max_{n^{*H}(i)} E\left(p^{*H}(i)y^{*H}(i)\right) - wn^{*H}(i). \quad (38)$$

The quantities $y^H(i)$ and y^{*H} are given by equations (17) and (18), respectively. The expectation is over all possible realizations of $\varepsilon(i)$ and whether a strike occurs, which determines the value of $k(i) \in \{0, \kappa\}$.

Similarly, the *Foreign* firm has productivity $z^F(i)$ and maximizes the expected profit $E\left(\Pi^F(i)\right)$:

$$E\left(\Pi^F(i)\right) = E\left(\pi^{*F}(i)\right) + E\left(\pi^F(i)\right),$$

where

$$E\left(\pi^{*F}(i)\right) = \max_{n^{*F}(i)} E\left(p^{*F}(i)y^{*F}(i)\right) - w^F n^{*F}(i), \tag{39}$$

$$E\left(\pi^F(i)\right) = \max_{n^F(i)} E\left(p^F(i)y^F(i)\right) - w^F n^F(i). \tag{40}$$

For a given realization of $\varepsilon(i)$ and labor inputs $n^H(i)$, $n^{*H}(i)$, $n^{*F}(i)$ and $n^F(i)$, the quantities $y^H(i)$, $y^{*H}(i)$, $y^{*F}(i)$ and $y^F(i)$ are determined by equations (17)-(20). For given P, P^*, Y and Y^*, the prices that clear all four markets simultaneously are given by equations (41)-(44) below.:

$$y^H(i) = \left(\frac{p^H(i)}{p(i)}\right)^{-\rho} \left(\frac{p(i)}{P}\right)^{-\sigma} Y, \tag{41}$$

$$y^F(i) = \left(\frac{\tau p^F(i)}{p(i)}\right)^{-\rho} \left(\frac{p(i)}{P}\right)^{-\sigma} Y, \tag{42}$$

$$y^{*H}(i) = \left(\frac{\tau p^{*H}(i)}{p^*(i)}\right)^{-\rho} \left(\frac{p^*(i)}{P^*}\right)^{-\sigma} Y^*, \tag{43}$$

$$y^{*F}(i) = \left(\frac{p^{*F}(i)}{p^*(i)}\right)^{-\rho} \left(\frac{p^*(i)}{P^*}\right)^{-\sigma} Y^*, \tag{44}$$

where the prices of the composite intermediate goods $y(i)$ and $y^*(i)$ are given by

$$p(i) = \left(p^H(i)^{1-\rho} + \left(\tau p^F(i)\right)^{1-\rho}\right)^{\frac{1}{1-\rho}} \tag{45}$$

and

$$p^*(i) = \left(\left(\tau p^{*H}(i)\right)^{1-\rho} + p^{*F}(i)^{1-\rho}\right)^{\frac{1}{1-\rho}}. \tag{46}$$

The terms $\left(\frac{p(i)}{P}\right)^{-\sigma} Y$ and $\left(\frac{p^*(i)}{P^*}\right)^{-\sigma} Y^*$ describe the final good producers' demand for $y(i)$ and $y^*(i)$ in *Home* and *Foreign*, respectively. The price ratios in the first term on the right hand side of equations (41)-(44) govern the market shares of the *Home* and *Foreign* producer in the domestic and export markets for good i, the importance of which we discuss in more detail below.

The *Foreign* producer selling in the *Home* market charges:

$$p^F(i) = \frac{\varepsilon^F(i)}{\varepsilon^F(i)-1}\frac{w^F}{z^F(i)}, \tag{47}$$

$$\varepsilon^F(i) \equiv \left(\omega^F(i)\frac{1}{\sigma} + (1-\omega^F(i))\frac{1}{\rho}\right)^{-1} \tag{48}$$

$$\omega^F(i) \equiv \frac{\tau p^F(i) y^F(i)}{p(i)y(i)} = 1 - \omega^H(i) \tag{49}$$

Producers selling in the *Foreign* market (identified by *) will charge:

$$p^{*H}(i) = \frac{\varepsilon^{*H}(i)}{\varepsilon^{*H}(i)-1}\frac{1}{z^H(i)} \tag{50}$$

$$p^{*F}(i) = \frac{\varepsilon^{*F}(i)}{\varepsilon^{*F}(i)-1}\frac{w^F}{z^F(i)}, \tag{51}$$

where $\varepsilon^{*H}(i)$ and $\varepsilon^{*F}(i)$ are the analogues of (22) and (48) in the *Foreign* market.

Using the demand functions (41)-(44) together with the optimal prices in (21), (45)-(47), and (50)-(51), we can characterize the maximal profit of a *Home* firm for any realization of $\{\varepsilon(i)\}_{i\in[0,1]}$ by

$$\begin{aligned}\Pi^H(i) \equiv& \pi^H(i) + \pi^{*H}(i)\\ =& z^H(i)^{\rho-1}\Big[\varepsilon^H(i)^{-\rho}\left(\varepsilon^H(i)-1\right)^{\rho-1}p(i)^{\rho-\sigma}E\left(P^\sigma Y\right)\\ &+ \varepsilon^{*H}(i)^{-\rho}(\varepsilon^{*H}(i)-1)^{\rho-1}p^*(i)^{\rho-\sigma}E\left(P^{*\sigma}Y^*\right)\Big].\end{aligned} \tag{52}$$

Similarly, we have

$$\begin{aligned}\Pi^F(i) \equiv& \pi^{*F}(i) + \pi^F(i)\\ =& \left(\frac{z^F(i)}{w^F}\right)^{\rho-1}\Big[\varepsilon^{*F}(i)^{-\rho}(\varepsilon^{*F}(i)-1)^{\rho-1}p^*(i)^{\rho-\sigma}P^{*\sigma-1}E\left(P^{*\sigma}Y^*\right)\\ &+ \varepsilon^F(i)^{-\rho}\left(\varepsilon^F(i)-1\right)^{\rho-1}p(i)^{\rho-\sigma}P^{\sigma-1}E\left(P^\sigma Y\right)\Big]\end{aligned} \tag{53}$$

for a *Foreign* intermediate producer of good i.

Importantly, P, P^*, Y and Y^* depend on the realizations of *all* $\{\varepsilon(i)\}_{i\in[0,1]}$, not just $\varepsilon(i)$. This implies that individual firms form expectations over these aggregate variables, and since the economy is populated by a continuum of firms indexed by $i \in [0,1]$, these expectations must be confirmed *ex post*.

Bargaining Protocol in the Quantitative Version For simplicity, we characterize the protocol for a single good i with two producers – *Home* and *Foreign* – who take the productivities and hiring decisions of all other firms producing goods $j \neq i$ as given.

1. At the beginning of each period, everyone observes the idiosyncratic productivities $\{z^H(i), z^F(i)\}_{i\in[0,1]}$, the two firms hire labor inputs $n^H(i)$, $n^{*H}(i)$, $n^{*F}(i)$, and $n^F(i)$ to maximize $E\left(\Pi^H(i)\right)$ and $E\left(\Pi^F(i)\right)$, where $\Pi^H(i)$ and $\Pi^F(i)$ are given by (52) and (53), respectively. Once the number of workers has been chosen, the firms can no longer adjust the size of their workforce for the remainder of the period.

2. The productivity shock $\varepsilon^H(i)$ is revealed to the *Home* firm, but not to the union.

3. The union makes a take-it-or-leave-it offer of $R(i)$, net of the competitive wage, to be paid out from the profits of the firm.

4.a. If the firm **accepts**, it produces using the workers it chose in 1., transfers $R(i)$ to the union and retains $\Pi^H(i) - R(i)$. The union splits $R(i)$ evenly among its $n^H(i) + n^{*H}(i)$ workers. The period ends.

4.r. If the firm **rejects**, the union calls a strike and production idles for fraction $\kappa \in (0, 1)$ of time. Workers are not paid during the strike.

As in the simple model, a fictitious arbiter allocates the fraction $\phi(i) \in (0, 1)$ of post-strike profits, denoted $\hat{\Pi}^H$, to the union. We assume that $\phi(i) = \phi^R$ for all $i \in [0, \lambda]$ (i.e. firms in Rust Belt) and $\phi(i) = \phi^S$ for all $i \in [\lambda, 1]$ (i.e. firms in Rest-of-Country). Unions in the Rust Belt have greater bargaining power that is captured by setting $\phi^R > \phi^S$. Arbitration is binding. The union distributes its share of post-strike profits to the workers on payroll. The period ends.

The union selects $R(i)$ to maximize its expected payoff. The problem can be solved by backward induction.

Union's Problem in the Quantitative Model. At stage 4. of the bargaining protocol, all labor inputs have been chosen and the productivity shocks have been revealed. There is no uncertainty and the prices $p^H(i)$, $p^F(i)$, $p^{*H}(i)$, $p^{*F}(i)$ solve equations (41)-(44). The firm has to decide between accepting or rejecting $R(i)$ by comparing the payoffs associated with 4.a. and 4.r. It accepts the request if

$$\Pi^H\left(\varepsilon^H(i)\right) - R(i) \geq (1 - \phi(i))\,\hat{\Pi}^H\left(\varepsilon^H(i)\right) \tag{54}$$

and rejects otherwise. We write profits as a function of $\varepsilon^H(i)$ to highlight that *ex post* profits depend on the realization of the productivity shock. Given $R(i)$, there is a cutoff value of $\varepsilon^H(i)$, denoted by $\tilde{\varepsilon}^H(i)$ that solves

$$\Pi^H\left(\tilde{\varepsilon}^H(i)\right) - R(i) = (1-\phi(i))\,\hat{\Pi}^H\left(\tilde{\varepsilon}^H(i)\right). \tag{55}$$

The union knows that the firm accepts if $\varepsilon^H(i) \geq \tilde{\varepsilon}^H(i)$ and rejects otherwise.

In Appendix C.2 we show that $\Pi^H(\varepsilon^H(i))$ increases in $\varepsilon(i)$ strictly faster than $\hat{\Pi}^H(\varepsilon^H(i))$ does. This implies there exists a strictly increasing one-to-one correspondence between $R(i)$ and $\tilde{\varepsilon}^H(i)$, which we denote as

$$\tilde{\varepsilon}^H(R) : \mathbb{R}^+ \mapsto \mathbb{R}^+. \tag{56}$$

The union maximizes total rents plus wage income for its affiliated workers:

$$\begin{aligned} R^*(i) = \arg\max_{R(i)} &\int_{\tilde{\varepsilon}^H(R)}^{\infty} \left[n^H(i) + n^{*H}(i) + R(i)\right] f(\varepsilon^H(i))d\varepsilon^H(i) \\ &+ \int_0^{\tilde{\varepsilon}^H(R)} \left[(1-\kappa)\left(n^H(i) + n^{*H}(i)\right) + \phi(i)\hat{\Pi}^H\left(\varepsilon^H(i)\right)\right] f\left(\varepsilon^H(i)\right) d\varepsilon^H(i), \end{aligned} \tag{57}$$

where $f(\varepsilon^H(i))$ is the probability density function for the shock $\varepsilon^H(i)$. The first integral takes into account realizations of $\varepsilon^H(i)$ where the firm accepts $R(i)$; the second integral is over shocks that lead to a rejection and hence a strike.

The first-order condition of the union's problem with respect to $R(i)$ relies on Leibniz's rule:

$$\begin{aligned} &1 - F\left(\tilde{\varepsilon}^H(R)\right) - \tilde{\varepsilon}^{H\prime}(R)\left[n^H(i) + n^{*H}(i) + R(i)\right] f\left(\tilde{\varepsilon}^H(R)\right) \\ &\quad + \tilde{\varepsilon}^{H\prime}(R)\left[(1-\kappa)\left(n^H(i) + n^{*H}(i)\right) + \phi(i)\hat{\Pi}^H\left(\tilde{\varepsilon}^H(R)\right)\right] f\left(\tilde{\varepsilon}^H(R)\right) = 0, \end{aligned}$$

which can be further simplified to

$$1 - F\left(\tilde{\varepsilon}^H(R)\right) - \tilde{\varepsilon}^{H\prime}(R)\left[\kappa\left(n^H(i) + n^{*H}(i)\right) + R(i) - \phi(i)\hat{\Pi}^H\left(\tilde{\varepsilon}^H(R)\right)\right] f\left(\tilde{\varepsilon}^H(R)\right) = 0, \tag{58}$$

where $F(\cdot)$ is the c.d.f. corresponding to $f(\cdot)$ and $\tilde{\varepsilon}^{H\prime}(R)$ is given by the total differential of the cutoff rule (55):

$$
\begin{aligned}
D(\tilde{\varepsilon}^H(R)) &\equiv \tilde{\varepsilon}^{H\prime}(R) \\
&= \Bigg(n^H(i) p^H(\tilde{\varepsilon}^H(R)) \frac{\varepsilon^H(\tilde{\varepsilon}^H(R)) - 1}{\varepsilon^H(\tilde{\varepsilon}^H(R))} + n^{*H}(i) p^{*H}(\tilde{\varepsilon}^H(R)) \frac{\varepsilon^{*H}(\tilde{\varepsilon}^H(R)) - 1}{\varepsilon^{*H}(\tilde{\varepsilon}^H(R))} \\
&\quad -(1-\phi)(1-\kappa) \left[n^H(i) \hat{p}^H(\tilde{\varepsilon}^H(R)) \frac{\hat{\varepsilon}^H(\tilde{\varepsilon}^H(R)) - 1}{\hat{\varepsilon}^H(\tilde{\varepsilon}^H(R))} + n^{*H}(i) \hat{p}^{*H}(\tilde{\varepsilon}^H(R)) \frac{\hat{\varepsilon}^{*H}(\tilde{\varepsilon}^H(R)) - 1}{\hat{\varepsilon}^{*H}(\tilde{\varepsilon}^H(R))} \right] \Bigg)^{-1}.
\end{aligned} \tag{59}
$$

where $p^H(\tilde{\varepsilon}^H(R))$, $p^{*H}(\tilde{\varepsilon}^H(R))$, $\hat{p}^H(\tilde{\varepsilon}^H(R))$, and $\hat{p}^{*H}(\tilde{\varepsilon}^H(R))$ are market-clearing prices for the *Home* firm with start-of-period productivity $z(i)$ when the realized intra-period productivity shock is equal to $\tilde{\varepsilon}^H(R)$. In particular, $\hat{p}^H(\tilde{\varepsilon}^H(R))$ and $\hat{p}^{*H}(\tilde{\varepsilon}^H(R))$ are the prices when the firm faces a strike. The fractions involving $\varepsilon^H(\tilde{\varepsilon}^H(R))$ and $\varepsilon^{*H}(\tilde{\varepsilon}^H(R))$ are the inverses of markups when the realized productivity shock is equal to $\tilde{\varepsilon}^H(R)$, again with the hat notation denoting cases where strikes are called.

After substituting (55) and (59) into the first-order condition (58) we get

$$
1 - F\left(\tilde{\varepsilon}^H(R)\right) - D(\tilde{\varepsilon}^H(R)) \left[\kappa \left(n^H(i) + n^{*H}(i) \right) + \Pi^H(\tilde{\varepsilon}^H(R)) - \hat{\Pi}^H(\tilde{\varepsilon}^H(R)) \right] f(\tilde{\varepsilon}^H(R)) = 0 \tag{60}
$$

so that the union's problem is re-specified in terms of the threshold productivity $\tilde{\varepsilon}^H(R)$ that satisfies (60). It is then straightforward to characterize the union's optimal request $R^*(i)$ using the $\tilde{\varepsilon}^H(R)$ that solves (60) and equation (55).

In Appendix C.3 we show that a unique $\tilde{\varepsilon}^H(R)$ and hence $R^*(i)$ maximizes the union's objective function. The probability that a firm rejects a request and a strike takes place is given by

$$
\text{Pr(strike)} = \frac{1}{2}\left[1 + \text{erf}\left(\frac{\tilde{\varepsilon}^H(R)}{\sigma_\varepsilon \sqrt{2}}\right)\right]. \tag{61}
$$

Firms take the union's $R(i)$ and the corresponding probability of a strike into account when they hire labor inputs in order to maximize the *ex ante* profits in equations (37)-(40).

Trade Balance. The trade balance condition is as follows:

$$
\int_0^1 \left(p^{*H}(i) \left[\tau y^{*H}(i)\right] - \left[\tau p^F(i)\right] y^F(i) \right) di = 0. \tag{62}
$$

Note that $p^H(i)$ and $p^F(i)$ are the f.o.b. ("free on board" or factory gate) prices. The prices of the composite intermediates are based on the c.i.f. ("cost including freight") prices.

C.2. Firms' *Ex Post* Profits

The profit functions (52) and (53) cannot be solved in closed form. We can, however, show that the firms' profits are strictly increasing in $\varepsilon(i)$ for given $\{\varepsilon(j)\}_{i\neq j}$. We formally show that *Home's* profit in the domestic market is a monotone increasing function of the productivity shock. The characterization of profits generated in the export market is available upon request.

Recall that the market shares of the *Home* and *Foreign* firms are given by

$$\omega^H(i) \equiv \frac{p^H(i)y^H(i)}{p(i)y(i)} = \left(\frac{p^H(i)}{p(i)}\right)^{1-\rho} \tag{63}$$

$$\omega^F(i) \equiv \frac{\tau p^F(i)y^F(i)}{p(i)y(i)} = \left(\frac{\tau p^F(i)}{p(i)}\right)^{1-\rho} = 1 - \omega^H(i). \tag{64}$$

By equation (42), we obtain

$$d\ln p^F(i) = \frac{\rho-\sigma}{\rho} d\ln p(i). \tag{65}$$

By definition of the sector price index, (45), we have

$$d\ln p(i) = \omega^H(i) d\ln p^H(i) + \omega^F(i) d\ln p^F(i). \tag{66}$$

Combining these two equations, we have

$$d\ln p^F(i) = \frac{(\rho-\sigma)\omega^H(i)}{\rho\omega^H(i) + \sigma\omega^F(i)} d\ln p^H(i). \tag{67}$$

Substituting this equation into the result of total differentiating the ratio of (41) and (42), we obtain

$$d\ln y^H(i) - d\ln y^F(i) = -\left(\omega^H(i)\frac{1}{\sigma} + \omega^F(i)\frac{1}{\rho}\right)^{-1} d\ln p^H = -\varepsilon^H(i) d\ln p^H. \tag{68}$$

Given the outcome of strikes, the only source of variation in output at the price-setting stage comes from the realization of productivity shock $z^H(i)$. Therefore, holding the strike outcome fixed, $d\ln y^H(i) = d\ln z^H(i)$ and $d\ln y^F(i) = 0$, so that the equation above implies

$$\frac{d\ln p^H(i)}{d\ln z^H(i)} = -\left(\omega^H(i)\frac{1}{\sigma} + \omega^F(i)\frac{1}{\rho}\right) = -\frac{1}{\varepsilon^H(i)} > -1 \tag{69}$$

and

$$\frac{d\ln p^H(i)y^H(i)}{d\ln z^H(i)} = \frac{d\ln p^H(i)}{d\ln z^H(i)} + 1 > 0. \tag{70}$$

Since labor cost is fixed, the *ex post* profits without strikes is strictly increasing in the productivity shock. Moreover, this equation also holds under strikes, so that the elasticity of sales to the productivity shock is the same regardless of strikes. Since strikes take out a fraction κ of output, the response of the level of sales to productivity shocks is larger when there is no strike. Putting these pieces together, we can write the ex post profits as strictly increasing functions of *Home* firm's productivity, which satisfy

$$\begin{aligned}\frac{d\pi^H(i)(z^H(i))}{dz^H(i)} = \frac{dp^H(i)y^H(i)}{dz^H(i)} &= l^H(i)p^H(i)\left(1 + \frac{z^H(i)}{p^H(i)}\frac{dp^H(i)}{dz^H(i)}\right) \\ &= l^H(i)p^H(i)\frac{\varepsilon^H(i) - 1}{\varepsilon^H(i)}\end{aligned} \tag{71}$$

and

$$\frac{d\hat{\pi}^H(i)(z^H(i))}{dz^H(i)} = (1-\kappa)l^H(i)\hat{p}^H(i)\frac{\hat{\varepsilon}^H(i) - 1}{\hat{\varepsilon}^H(i)}, \tag{72}$$

so that

$$\frac{d\pi^H(z^H(i))}{dz^H(i)} > \frac{d\hat{\pi}^H(z^H(i))}{dz^H(i)} > 0 \tag{73}$$

where $\hat{\pi}^H$, $\hat{p}^H$, and $\hat{\varepsilon}^H$ denote the corresponding variables in cases where strikes take place.

Analogously, we can derive that the *Home* firm's profits overseas is also strictly increasing in the productivity shock regardless of strikes, and satisfies

$$\frac{d\pi^{*H}(i)(z^H(i))}{dz^H(i)} = l^{*H}(i)p^{*H}(i)\frac{\varepsilon^{*H}(i) - 1}{\varepsilon^{*H}(i)}, \tag{74}$$

$$\frac{d\hat{\pi}^{*H}(i)(z^H(i))}{dz^H(i)} = (1-\kappa)l^{*H}(i)\hat{p}^{*H}(i)\frac{\hat{\varepsilon}^{*H}(i) - 1}{\hat{\varepsilon}^{*H}(i)}, \tag{75}$$

and

$$\frac{d\pi^{*H}(z^H(i))}{dz^H(i)} > \frac{d\hat{\pi}^{*H}(z^H(i))}{dz^H(i)} > 0. \tag{76}$$

Define

$$\Pi^H(z^H(i)) = \pi^H(z^H(i)) + \pi^{*H}(z^H(i)), \tag{77}$$

we have

$$\frac{d\Pi^H(z^H(i))}{dz^H(i)} > \frac{d\hat{\Pi}^H(z^H(i))}{dz^H(i)} > 0. \tag{78}$$

C.3. Uniqueness of $R(i)$

Let the idiosyncratic productivity shock $\varepsilon^H(i)$ follow a normal distribution with mean μ_ε and standard deviation σ_ε. Further simplification yields

$$\frac{1-\Phi((\ln \tilde{z}^H - \bar{z})/\sigma_z)}{\varphi((\ln \tilde{z}^H - \bar{z})/\sigma_z)} = D(\tilde{z}^H)\left[\kappa w^H(l^H + l^{*H}) + \Pi^H(\tilde{z}^H) - \hat{\Pi}^H(\tilde{z}^H)\right], \tag{79}$$

where $\Phi(\cdot)$ and $\varphi(\cdot)$ denote the CDF and PDF of the standard normal distribution. It is easy to see that the right-hand side of the equation is positive and increasing in $\tilde{z}^H$. The left-hand side is the inverse of the inverse Mill's ratio and is equal to $1/E[W|W > (\ln \tilde{z}^H - \bar{z})/\sigma_z]$ where W is a random variable following standard normal distribution. Therefore, the left-hand side expression is strictly decreasing in $\tilde{z}^H$ and satisfies

$$\lim_{\tilde{z}^H \to 0} \frac{1-\Phi((\ln \tilde{z}^H - \bar{z})/\sigma_z)}{\varphi((\ln \tilde{z}^H - \bar{z})/\sigma_z)} = \infty \tag{80}$$

and

$$\lim_{\tilde{z}^H \to \infty} \frac{1-\Phi((\ln \tilde{z}^H - \bar{z})/\sigma_z)}{\varphi((\ln \tilde{z}^H - \bar{z})/\sigma_z)} = 0. \tag{81}$$

Therefore, for any value of $\sigma > 1$, $\phi \in (0,1)$, and $\kappa \in (0,1)$ There exists a unique solution for $\tilde{z}^H$ that satisfies (79), hence a unique solution of R.

C.4. Numerical Algorithm

Numerical methods are used to compute the solution. In lieu of a continuum, we populate the economy by $2 \times I$ firms, which are indexed by $i \in \{1, \ldots, I\}$. Each i has two producers, one in *Home* and one in *Foreign*. We maintain the assumption that the market for each good i is small, which implies that the two producers of this good take the decisions of all producers $j \neq i$ in *Home* and *Foreign* as given. We choose $I = 1793$, which is the number of U.S. state-industry (manufacturing only) pairs at the 3-digit SIC level in the data.

The state vector of the economy is the set of 3,586 firm productivities $\{z^H(i), z^F(i)\}_{i\in\{1,\ldots,I\}}$. The model's initial period will correspond to the year 1950, which is the first observation in the dataset. The initial period productivities are drawn from a log-normal distribution with normalized mean $\mu = 0$ and variance σ_z^2.

The period-by-period solution algorithm relies on initial guesses for aggregate expenditures, the foreign wage, the $4 \times I$ matrix of labor inputs, and the $1 \times I$ vector of threshold productivities. These guesses are partitioned into three groups, which are organized hierarchically and this structure is mirrored by the solution algorithm.

Given the total price-adjusted expenditures $P^{\sigma-1}(PY)$ and $P^{*\sigma-1}(P^*Y^*)$ in *Home* and *Foreign*, respectively, the foreign wage w^F, and the set of labor inputs $\{n^H(i), n^{*H}(i), n^F(i), n^{*F}(i)\}_{i\in\{1,\ldots,I\}}$, we find the threshold productivities $\tilde{\varepsilon}$ that satisfy equation (60) for each i in step 1 of the algorithm.

Next, given the thresholds $\{\tilde{\varepsilon}\}_{i\in\{1,\ldots,I\}}$, we find the labor allocation $\{n^H(i), n^{*H}(i), n^F(i), n^{*F}(i)\}_{i\in\{1,\ldots,I\}}$ that satisfies the *ex ante* demand equations (45)-(51). This is the second step. We iterate over steps 1 and 2 to convergence of the productivity thresholds and labor inputs.

We then verify if w^F satisfies the trade balance condition and whether the P, P^*, Y, and Y^* implied by the solution in steps 1 and 2 satisfy the labor market clearing condition. This is the third step of the algorithm.

If necessary, we update $P^{\sigma-1}(PY)$, $P^{*\sigma-1}(P^*Y^*)$, and w^F and iterate over the three-step procedure to convergence. In all three steps we use standard numerical methods to solve systems of non-linear equations.

C.5. Extension with Services

A natural extension to our model is to include a service sector. The benchmark calibration ignored the service sector and assumed that the entire economy was based on manufacturing. Clearly this is false, though: the U.S. service sector grew in secular fashion from about 70 percent of the workforce in 1950 to almost 90 percent by 2000. This begs the question: to what extent would the model's quantitative conclusions change if it were to include a service sector in addition to manufacturing?

To help answer this question, consider a simple extension of the model that includes both manufacturing and service sectors, with structural change from the former to the latter over time. Let there be a representative firm that produces final goods in region j from tradable manufactured goods and non-tradable services. Let the final-goods production technology in region j be:

$$Y^j = \left(\mu^{\frac{1}{\theta}} Y_m^{j\,\frac{\theta-1}{\theta}} + (1-\mu)^{\frac{1}{\theta}} Y_n^{j\,\frac{\theta-1}{\theta}}\right)^{\frac{\theta}{\theta-1}}, \tag{82}$$

where Y_m^j and Y_n^j denote the amount of manufacturing goods and services used to produce the final good, θ denotes the elasticity of substitution between the manufactured good and local service, and μ is a weight parameter on manufacturing. Let the non-tradable services be produced by a representative firm in each region with the linear technology $Y_n^j = z_n^j l_n^j$, where z_n^j is the labor productivity of services in region j, and l_n^j is the amount of labor employed in region j for services production.

The literature on structural change has largely agreed that the elasticity of substitution between manufactured goods and services, θ, is close to zero (see e.g. Herrendorf, Rogerson, and Valentinyi, 2014; Garcia-Santana, Pijoan-Mas, and Villacorta, 2016). In our model, this would mean that Y_m and Y_n are strong complements. As a result, when manufacturing activity moves out of a region, there is little scope for consumers to simply substitute services for manufactures. Instead, service activity moves out of the region almost one-for-one with manufacturing activity. This suggests that adding a service sector is unlikely to change the model's quantitative predictions for the Rust Belt's decline. Indeed, this is consistent with the results in a previous version of the model that accounted for structural change explicitly (Alder, Lagakos, and Ohanian, 2017).[1]

C.6. Identification

Given the fairly large number of moments and targets in our calibration, it is useful to provide a systematic analysis of how each parameter is identified from the data. To that end, we compute the elasticity of each moment in the model to each parameter, starting from the calibrated parameter values. This amounts to re-solving the model one additional time for each parameter, each time increasing the value of one parameter by one percent while leaving all other parameters the same. Table A.5 reports the values of these elasticities for nine of the twelve parameters and moments in the calibration. For expositional purposes we omit the trade parameters τ_0, δ_τ and ζ_R, and the trade moments from the Table, and we instead discuss those informally here. We print the largest elasticity in each *column* in bold face, to highlight which moments are most sensitive to each parameter, and we underline the largest elasticity in each *row* to illustrate which parameter has the largest effect on each moment.

As Table A.5 shows, several of the moments and parameters are tightly linked to one another. The Rust Belt's initial employment share is most responsive to λ, and vice versa. The same is true of the average productivity growth and α (the scale parameter in the investment cost function), and of the work stoppage rate and σ_ε (the variance of firm productivity shocks).

[1]The working paper is available at `https://ssc.wisc.edu/~sdalder/RB-WP-2017.pdf`.

Table A.5: Elasticity of Moments to Parameters

	λ	$\sigma_{z,0}$	α	s	τ_0	ζ_R	δ_τ	σ	ϕ_R	σ_ε	ϕ_S	ρ
R.B. initial empl. share	<u>0.9</u>	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0
Initial var of log empl.	0.0	**2.0**	0.0	0.0	0.0	0.0	0.0	<u>3.0</u>	0.0	0.0	0.0	0.2
Labor prod. growth	-0.1	<u>0.5</u>	**-0.5**	0.4	0.0	-0.1	0.4	0.3	-0.1	0.0	0.0	-0.1
Inv-to-VA ratio	-0.1	0.1	0.0	**1.0**	-0.1	1.3	<u>-3.1</u>	-1.1	-0.1	0.0	0.0	-0.1
R.B. import to sales, 1958	**1.1**	-0.5	0.0	0.0	**-1.6**	8.7	<u>-12.9</u>	-4.3	0.0	0.0	0.0	-1.3
R.B. import to sales, 1990	0.3	-0.2	-0.2	0.2	-1.4	**27.3**	<u>**-56.6**</u>	-1.8	0.2	0.0	0.0	-0.1
Mfg import to sales, 1990	0.5	0.2	-0.1	0.1	-1.2	12.3	<u>-50.3</u>	-1.4	0.0	0.0	0.0	-0.3
Labor share	0.1	0.0	0.0	0.0	0.0	0.0	0.0	<u>0.4</u>	0.1	0.0	0.0	0.0
R.B. wage premium	0.5	0.0	0.0	0.0	0.0	-0.2	0.4	<u>-3.0</u>	1.0	-0.8	0.0	-0.2
R.B. work stoppages	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**1.0**	<u>**1.3**</u>	0.0	0.0
R.O.C. work stoppages	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	<u>1.1</u>	**0.2**	0.0
Reg. coeff: conflict	-0.5	-0.8	-0.3	0.6	-0.2	<u>11.1</u>	-9.9	**-5.0**	0.6	-0.1	0.0	**3.9**

Note: This table reports the elasticity of each moment to each parameter, calculated from one-percent numerical derivatives of each parameter starting from the calibrated parameter values (except for ζ_R and δ_τ). For ζ_R and δ_τ, the numerical derivatives are calculated from deviations of $1/50$ of a percentage and $1/35$ of a percentage. The largest elasticity (in absolute value) in each column is printed in bold faced. The largest elasticity (in absolute value) in each row is printed in underline.

In other cases the mapping between parameters and moments is somewhat more intricate. The parameter $\sigma_{z,0}$ most strongly affects the initial variance in employment across goods (i.e. the elasticity of 2.1 in the second row, second column), though this moment also responds strongly to the elasticity of substitution, σ (i.e. the elasticity of 3.0 in the second row, fifth column). Similarly, the savings parameter s has the largest effect on the investment-to-VA ratio, though this moment also responds most strongly to σ. The parameter σ also has the largest impact on the labor share of GDP. In fact, this moment responds to little else. Intuitively, this is because σ largely controls the average markup in the economy, and hence the economy's non-labor income share.

The labor bargaining parameters, ϕ_R and ϕ_S, have the largest impacts on the Rust Belt wage premium and work stoppage rate in the rest of the country. The former also has a substantial impact on the work stoppage rate in the Rust Belt, and the conflict coefficient in the regression of log employment growth on work stoppage rates. This regression coefficient is informed by several parameters, with the largest responses being to the elasticities of substitution σ and ρ, and ϕ_R also playing an important role. A larger value of

σ leads to a less negative slope since it reduces the size of the average surplus and hence the scope for conflict. A larger value of ρ leads to a more negative slope since it increases the substitution from home to foreign varieties of Rust Belt goods, and – since trade is balanced – from foreign to home varieties of goods made in the rest of the country. A higher ϕ_R raises rates of conflict and wage premia in the Rust Belt, which results in a larger negative impact of conflict on employment.

The trade parameters have intuitive mappings to the data. Changes in τ_0, the initial trade cost, have the largest impact on the 1958 import share in the Rust Belt. Naturally, τ_0 also affects import shares in later years in both regions. Changes in ζ_R, the productivity boost for foreign varieties of Rust Belt goods, have the largest impact on the 1990 import share in the Rust Belt. The parameter δ_τ, which governs the annual decline in trade costs, also has the largest impact on the Rust Belt's import share in 1990, though it also has a substantial impact on the manufacturing sector's import share in 1990.

C.7. Alternative Cost Function

In our quantitative work, we also considered an alternative calibration of the model with a variation of the investment cost function in equation (5), namely:

$$C(x_t(i), z_t(i), \mathcal{Z}_t) = \frac{\alpha x_t(i)^2 z_t(i)^{\rho-1}}{\mathcal{Z}_t^{\rho-1}}, \tag{83}$$

which replaces $\sigma - 1$ in the benchmark function with $\rho - 1$ as the power associated with the firm's productivity (in the numerator) and the weighted average of all firms' productivities (in the denominator). The rationale for the original specification is that it implies balanced growth when the economy is closed and there is no labor conflict. As the economy becomes more open and firms are competing more with their foreign counterparts, the "effective" substitution elasticity shifts from σ toward ρ. To account for this effect, we re-calibrate the model using this alternative specification of the cost function. We find that re-calibrating the model with this alternative cost function results in little difference in practice on either the behavior of the model's growth rates or its predictions for the Rust Belt's decline. The re-calibrated model predicts a 10.1 percentage point decline in the Rust Belt, which is 55.2 percent of the actual value. In our benchmark calibration, the model generates a decline of 10.0 percentage points (54.6 percent of the actual drop).

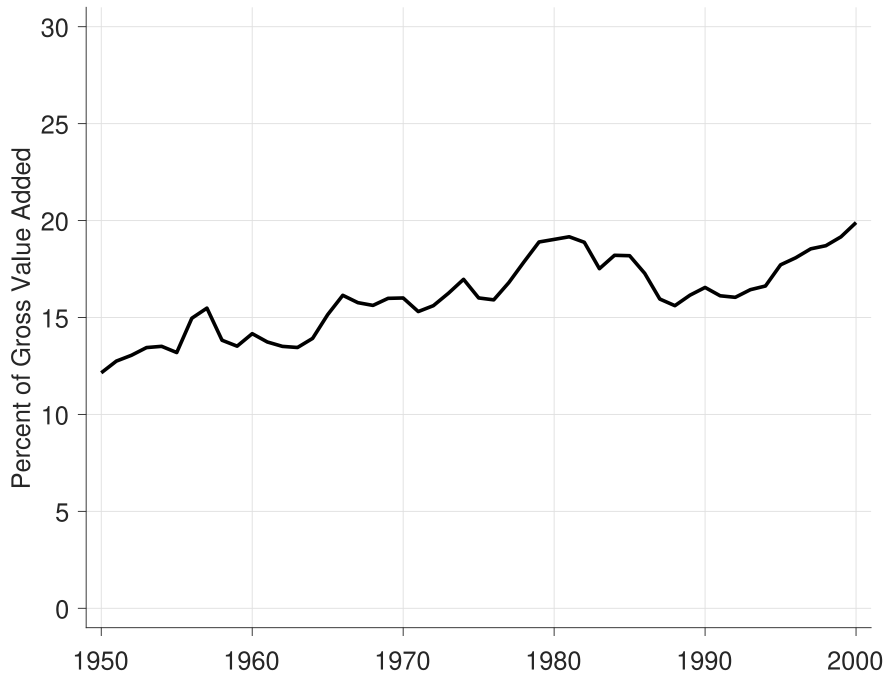

Figure A.1: Firm Investment-to-Value Added Ratio

C.8. Investment Rate

Figure C.8 plots the ratio of investment to value added in the U.S. corporate non-financial sector. The data come from the Federal Reserve Board's Financial Accounts of the United States.

The benchmark calibration in section 5.1 assumes a constant investment rate of 16 percent over the entire period, whereas investment rises from an average of 13.6 as a percent of value added in the 1950s to 17.4 percent in the 1990s. The sensitivity analysis in section 5.3 adds a time trend to account for this secular increase in the investment rate.

D. Regional Cost-of-Living Differences

One potential explanation of the Rust Belt's wage premium we document in Section 2 is that the cost of living was higher in the Rust Belt than elsewhere in the United States. To address this hypothesis, we draw on the study of the U.S. Bureau of Labor Statistics (1967) that estimates costs of living across 39 U.S. metropolitan areas and 4 regional averages of urban areas not already included in one of the metropolitan areas. Their estimates are not exactly cost of living differences, since they adjust the expenditure basket in each region to take into consideration e.g. higher heating costs in colder areas. But they do attempt to capture the cost of an average budget for a family of "moderate living standards" in each city in question.

Table A.6: Average Cost of Living in 1966, by U.S. City (U.S. = 100)

	Region		
	Rust Belt	Rest of Country	Difference
All cities	100.4	99.1	1.3 (0.28)
Excluding non-metro areas	101.1	99.8	1.3 (0.28)
Excluding Honolulu, HI	101.1	98.8	2.2 (0.12)
Excluding New York, NY	100.3	98.8	1.5 (0.22)

Note: The table reports the average cost of living in 1966 for cities in the Rust Belt and in the rest of the country, constructed by the BLS (1967). The overall average cost of living in urban areas is set to be 100. The right-hand column is the simple difference between the Rust Belt and the rest of the country, and below that, a p-value of the t-test that the means are the same. The first row includes 39 cities and averages for 4 non-metropolitan areas, in the northeast, north central, south and west. The second row includes only the 39 cities. The third row excludes Honolulu, and the last excludes Honolulu and New York City.

To compare average costs of living in the Rust Belt and elsewhere, we classify each city as being in the Rust Belt or in the rest of the country. The Rust Belt cities are: Buffalo, NY; Lancaster, PA; New York, NY; Philadelphia, PA; Pittsburgh, PA; Champaign-Urbana, IL; Chicago, IL; Cincinnati, OH; Cleveland, OH; Dayton, OH; Detroit, MI; Green Bay, WI; Indianapolis, IN; and Milwaukee, WI. The other cities are Boston, MA; Hartford, CT; Portland, ME; Cedar Rapids, IA, Kansas City, MO; Minneapolis, MN; St. Louis, MI; Wichita, KS; Atlanta, GA, Austin, TX; Baltimore, MD; Baton Rouge, LA; Dallas, TX; Durham, NC; Houston, TX; Nashville, TN; Orlando, FL; Washington, DC; Bakersfield, CA; Denver, CO; Honolulu, HI; Los Angeles, CA; San Diego, CA; San Francisco, CA; and Seattle, WA.

Table A.6 reports the averages across all 43 cities and non-metropolitan areas, compared to the U.S. average for all urban areas, which is normalized to 100. The Rust Belt has an average cost of 100.4, compared to 99.1 outside of the Rust Belt, for a difference of 1.3 percentage points. The p-value of this difference is 0.28, indicating that the difference is statistically insignificant at any conventional significance level. The second row excludes the four non-metropolitan areas. Not surprisingly, the average cost of living is higher in both regions, as larger urban areas tend to be more expensive. The difference is still 1.3 and statistically insignificant. The third row excludes Honolulu, the city with the highest cost of living, at 122. This brings the average cost of living down in the rest of the county, and raise the difference to 2.2 percentage points, though the p-value is 0.12. The last row excludes New York City, which has the second highest cost of living, at 111. New York City is in the Rust Belt, according to our definition, but not often thought of as a "Rust Belt" city. The Rust Belt is now 1.5 percentage points more expensive than the rest of the country, with a p-value of 0.22.

In summary, in none of the sample restrictions is the Rust Belt more than two percentage points more expensive than the rest of the country, and in all cases the difference is statistically insignificant. This casts substantial doubt on the hypothesis that workers in the Rust Belt earned higher wages in order to compensate them for higher costs of living.

E. Low Productivity Growth in Rust Belt Manufacturing Industries

In this section we examine labor productivity growth patterns for U.S. manufacturing industries. These data are not directly comparable to the model's predictions since they are not available at the state or other regional level. Hence it is impossible to compare how producers within the same industry fare differently across different regions. Therefore, our approach is to focus on measures of productivity growth in a broad set of industries by matching productivity data by industry to census data containing the geographic location of employment for each industry. This allows us to compare productivity growth in the industries most common in the Rust Belt to other industries.

To identify which industries are predominantly located in the Rust Belt, we match NBER industries (by SIC codes) to those in the IPUMS census data (by census industry codes). In each industry, we then compute the fraction of employment located in the Rust Belt. We define "Rust Belt industries" to be those whose employment share in the Rust Belt is more than one standard deviation above the mean. In practice, this turns out to be a cutoff of at least 68 percent of industry employment located in the Rust Belt.

Table A.7 reports productivity growth rates for the Rust Belt industries and their average over time. Productivity growth is measured as the growth in real value added per worker, using industry-level price indices as deflators. The first data column reports productivity growth in each industry, and the Rust Belt weighted average, for the period 1958 to 1985. On average, productivity growth rates were 2.0 percent per year in Rust Belt industries and 2.6 percent in all manufacturing industries. Productivity growth rates

Table A.7: Labor Productivity Growth in Rust Belt Industries

	Annualized Growth Rate, % 1958-1980	1980-1997
Blast furnaces, steelworks, rolling & finishing mills	1.1	4.3
Engines and turbines	2.1	2.2
Iron and steel foundries	1.6	1.4
Metal forgings and stampings	1.7	1.5
Metalworking machinery	1.0	3.1
Motor vehicles and motor vehicle equipment	2.1	3.5
Photo equipment and supplies	5.5	3.7
Railroad locomotives and equipment	3.0	-0.4
Screw machine products	0.4	1.9
Rust Belt weighted average	2.0	2.9
Manufacturing weighted average	2.4	2.9

Note: Rust Belt Industries are defined as industries whose employment shares in the Rust Belt region in 1975 are more than one standard deviation above the mean of all industries. Labor Productivity Growth is measured as the growth rate of real value added per worker. Rust Belt weighted average is the employment-weighted average productivity growth rate for Rust Belt industries. Manufacturing weighted average is the employment-weighted average productivity growth across all manufacturing industries. Source: Authors' calculations using NBER CES productivity database, U.S. census data from IPUMS, and the BLS.

in the Rust Belt were much higher between 1985 and 1997 than before, averaging 4.2 percent per year, compared to 3.2 percent for all manufacturing industries. For the whole period, the Rust Belt industries had slightly lower productivity growth (2.6 percent) than all manufacturing industries (2.8 percent).

Productivity growth in Rust Belt industries picked up after 1985. In the largest single Rust Belt industry, blast furnaces & steel mills, productivity growth averaged just 0.9 percent per year before 1985 but rose substantially to an average of 7.6 percent per year after 1985. Large productivity gains after 1985 are also present in all but one of the nine industries most common in the Rust Belt. We also find that investment rates increased substantially in most Rust Belt industries after 1985, rising from an average of 4.8 percent to 7.7 percent per year.

F. Bargaining under Asymmetric Information as in Card (1990)

According to equation (9) in Section 3.3 profits as a function of the realized productivity shock are of the form

$$Ae^{(\sigma-1)\varepsilon},$$

where $\sigma > 1$, and

$$A = \left(\frac{\sigma-1}{\sigma}\frac{P}{w}z\left(i\right)\right)^{\sigma-1}\frac{X}{\sigma}$$

is a constant that summarizes the elements that are exogenous to the union's problem and ε is the transitory productivity shock. For a firm dealing with a labor union, the firm's retained profits follow

$$\pi(\varepsilon) = A(1-\kappa(\varepsilon))^{\sigma-1}e^{\varepsilon(\sigma-1)}$$

where $\kappa \in [0,1]$ is the endogenous length of the strike.

The transitory productivity shock ε follows a uniform distribution with support $[-\bar{\varepsilon}, \bar{\varepsilon}]$. The union knows the distribution but the realization of ε is private information to the firm. The union chooses a shared profits-strike schedule $R(\kappa)$ that maximizes its *ex ante* payoff, knowing that the firm will choose the optimal length of strike with its private information on realized productivity.

Following Card (1990), we write the problem analytically as the union choosing a profit-sharing schedule $R\left(\varepsilon\right)$ and a strike schedule $\kappa\left(\varepsilon\right)$, subject to the incentive compatibility constraint that the firm is willing to reveal the productivity shock truthfully and the individual rationality constraint that the profits are large enough for the firm to retain non-negative earnings in every state.

Let $\hat{\pi}(\hat{\varepsilon}, \varepsilon)$ denote the post-negotiation profits retained by the firm, where $\hat{\varepsilon}$ is the productivity shock declared by the firm and ε is the true state. Let $\hat{\pi}(\varepsilon) \equiv \hat{\pi}(\varepsilon, \varepsilon)$. Then $R(\varepsilon) = \pi(\varepsilon) - \hat{\pi}(\varepsilon)$ and

$$\hat{\pi}(\hat{\varepsilon}, \varepsilon) = A(1-\kappa(\hat{\varepsilon}))^{\sigma-1}e^{\varepsilon(\sigma-1)} - R(\hat{\varepsilon}) = \hat{\pi}(\hat{\varepsilon}) + A(1-\kappa(\hat{\varepsilon}))^{\sigma-1}\left(e^{\varepsilon(\sigma-1)} - e^{\hat{\varepsilon}(\sigma-1)}\right).$$

The incentive compatibility constraint requires that

$$\hat{\pi}(\varepsilon) \geq \hat{\pi}(\hat{\varepsilon}, \varepsilon) = \hat{\pi}(\hat{\varepsilon}) + A(1-\kappa(\hat{\varepsilon}))^{\sigma-1}\left(e^{\varepsilon(\sigma-1)} - e^{\hat{\varepsilon}(\sigma-1)}\right),$$

which implies that

$$
\begin{aligned}
A(1-\kappa(\varepsilon))^{\sigma-1}\left(e^{\varepsilon(\sigma-1)}-e^{\hat{\varepsilon}(\sigma-1)}\right) &\geq \hat{\pi}(\varepsilon)-\hat{\pi}(\hat{\varepsilon}) \\
&\geq A(1-\kappa(\hat{\varepsilon}))^{\sigma-1}\left(e^{\varepsilon(\sigma-1)}-e^{\hat{\varepsilon}(\sigma-1)}\right)
\end{aligned}
\tag{84}
$$

Since κ is between 0 and 1, (84) implies that $\hat{\pi}(\cdot)$ is weakly increasing. We also observe that $\kappa(\cdot)$ is weakly decreasing. Dividing (84) by $\varepsilon-\hat{\varepsilon}$ and taking the limit $\varepsilon-\hat{\varepsilon}\to 0$, we obtain:

$$
\hat{\pi}'(\varepsilon)=(\sigma-1)A(1-\kappa(\varepsilon))^{\sigma-1}e^{\varepsilon(\sigma-1)}=(\sigma-1)\pi(\varepsilon)
$$

Note that since $e^{\varepsilon(\sigma-1)}$ is strictly increasing and strictly convex in ε and $\kappa(\varepsilon)$ is weakly decreasing, $\hat{\pi}'(\varepsilon)$ is strictly increasing and $\hat{\pi}(\varepsilon)$ is strictly convex.

The individual rationality constraint requires that $\hat{\pi}(\varepsilon)\geq 0$ for any realization of ε. Since $\hat{\pi}(\varepsilon)$ is increasing, the constraint is satisfied if and only if $\widehat{\pi}(-\bar{\varepsilon})\geq 0$.

These conditions also imply a bound on the maximum shared profits associated with a given strike mechanism. For any incentive-compatible wage and strike function satisfying $\hat{\pi}(-\bar{\varepsilon})=0$ let $\tilde{\varepsilon}$ denote the lowest value of ε such that $\kappa(\varepsilon)=0$. The probability of a strike is then $\text{Prob}(\varepsilon<\tilde{\varepsilon})$. Incentive compatibility requires that the firm shares the same amount of "no-strike" profits $R(\varepsilon)$ for all $\varepsilon\geq\tilde{\varepsilon}$. The amount that the union can achieve without any strike is $\pi(-\bar{\varepsilon})$. In summary, incentive compatibility and individual rationality are satisfied if and only if $\hat{\pi}(-\bar{\varepsilon})\geq 0, \kappa(\varepsilon)$ is decreasing, and

$$
\hat{\pi}(\varepsilon)=\int_{-\bar{\varepsilon}}^{\varepsilon}(\sigma-1)\pi(v)dv.
$$

The problem of maximizing the *ex ante* payoff $\mathbb{E}[R(\varepsilon)]$ of the union subject to incentive compatibility and individual rationality is equivalent to

$$
\max_{\kappa(\varepsilon)}\int_{-\bar{\varepsilon}}^{\bar{\varepsilon}}\left(A(1-\kappa(\varepsilon))^{\sigma-1}e^{\varepsilon(\sigma-1)}-\hat{\pi}(\varepsilon)\right)f(\varepsilon)d\varepsilon,
$$

subject to

$$
\begin{aligned}
&\hat{\pi}(-\bar{\varepsilon})=0,\\
&1\geq\kappa(\varepsilon)\geq 0,\\
&\hat{\pi}'(\varepsilon)=(\sigma-1)A(1-\kappa(\varepsilon))^{\sigma-1}e^{\varepsilon(\sigma-1)},\\
&\kappa(\varepsilon)\text{ weakly decreasing,}
\end{aligned}
$$

and $f(\varepsilon)=1/(2\bar{\varepsilon})$ is the density function of ε.

Following Card (1990), we solve this problem by conventional optimal control techniques, treating κ as the control variable and $\hat{\kappa}$ as the state variable. The Hamiltonian function is $H(\hat{\pi}, \kappa, \varepsilon) = \left(A(1-\kappa)^{\sigma-1}e^{\varepsilon(\sigma-1)} - \hat{\pi}\right) f(\varepsilon) + \mu(\varepsilon)(\sigma-1)A(1-\kappa)^{\sigma-1}e^{\varepsilon(\sigma-1)}$ where μ is the co-state variable. The necessary conditions for an optimum are

$$\frac{\partial H}{\partial \kappa} = -f(\varepsilon) - \mu(\varepsilon)(\sigma-1) = 0, \tag{85}$$

$$\frac{\partial H}{\partial \hat{\pi}} = -f(\varepsilon) = -\mu'(\varepsilon), \tag{86}$$

and

$$\mu(\bar{\varepsilon}) = 0. \tag{87}$$

Using (86) and (87), the value of the co-state variable can be written as

$$\mu(\varepsilon) = \mu(\bar{\varepsilon}) - \int_{\varepsilon}^{\bar{\varepsilon}} f(v)dv = F(\varepsilon) - 1.$$

Substituting into (85), the first-order condition for an interior strike length can be written as

$$\frac{f(\varepsilon)}{1-F(\varepsilon)} = \sigma - 1,$$

which is the hazard function of the distribution. The cutoff value for ε is given by

$$\tilde{\varepsilon} \equiv \bar{\varepsilon} - \frac{1}{\sigma-1}.$$

Since the first-order condition is independent of κ, we do not have an interior solution for $\kappa(\varepsilon)$. The expression for the cutoff value suggests that there is no strike when $\varepsilon \geq \tilde{\varepsilon}$ and a strike takes place with length $\kappa = 1$ when $\varepsilon < \tilde{\varepsilon}$. With this cutoff rule, incentive compatibility requires that

$$\hat{\pi}(\tilde{\varepsilon}) = 0.$$

Otherwise the union has incentives to raise the request for the no-strike scenario and the firm still accepts. It follows that

$$R(\tilde{\varepsilon}) = \pi(\tilde{\varepsilon}) - \hat{\pi}(\tilde{\varepsilon}) = \pi(\tilde{\varepsilon}) = Ae^{\tilde{\varepsilon}(\sigma-1)} = Ae^{\bar{\varepsilon}(\sigma-1)-1} \tag{88}$$

and the probability of a strike is given by

$$F(\tilde{\varepsilon}) = 1 - \frac{1}{2\bar{\varepsilon}(\sigma-1)}. \tag{89}$$

Note that the values of $R(\tilde{\varepsilon})$ and $F(\tilde{\varepsilon})$ are identical to those implied by the bargaining protocol in section 3.3 when the exogenous strike length is set to $\kappa = 1$ (see equations (12) and (13) in section 3.5). In this case, the union's bargaining power ϕ plays no role and variations in the wage premium and strike frequency are driven by $\bar{\varepsilon}$, which governs the information asymmetry, and by σ, which governs markups and thus the surplus over which the union and the firm are bargaining.

$R(\tilde{\varepsilon})$ and $F(\tilde{\varepsilon})$ are increasing functions of $\bar{\varepsilon}$, provided that $\bar{\varepsilon} \geq \frac{1}{2(\sigma-1)}$. Note that when $\bar{\varepsilon} = \frac{1}{2(\sigma-1)}$, (89) implies that no strikes take place. Equation (88) then implies that the union can extract strictly positive rents even when the information asymmetry is sufficiently small to avoid labor conflict. This result stems from the union's ability to appropriate all profits in the worst case scenario where $\varepsilon = -\bar{\varepsilon}$ and this, in turn, is a consequence of the union's first-mover advantage in the bargaining protocol. When the information asymmetry is in the range $\bar{\varepsilon} \in \left[0, \frac{1}{2(\sigma-1)}\right)$ we are in a corner with no strikes.

To the extent that we observe significant differences in the frequency of strikes and the size of the wage premium between the Rust Belt and other regions, this alternative model suggests that they must be the result of cross-regional variation in the labor-management information asymmetry and/or in the firms' pricing power. The empirical evidence for this sort of regional variation, however, is scant.

The salient changes across time and space are more legal in nature, such as the expansion of Right-to-Work legislation or the wider use of replacement workers starting in the 1980s, which undermined the effectiveness of the strike threat as a bargaining tool. One way to capture this stylized fact in the model is to allow some firms to "claim" the power to make take-it-or-leave-it offers from the union. Since the firm has perfect information and the union's outside option is zero, the firm will claim all profits. As an increasing share of firms gain the power to make these offers, the aggregate union rent in the Rust Belt will mirror the evolution of the strike rate.

To illustrate the change quantitatively, we perform a simple numerical exercise of the model that abstracts from investment and changes in firm-level employment. We impose $A = 1$ for all firms in all years. Let ψ denote the fraction of Rust Belt firms that can make a take-it-or-leave-it offer. We assume $\psi = 0$ before 1978 and we set the substitution elasticity to $\sigma = 2.48$, as in our benchmark calibration. To match the pre-1978 average rate of work stoppages of 19.2 percent we set $\bar{\varepsilon} = 0.418$. Beginning in 1978, the fraction of Rust Belt firms that gains the power to make offers rises in a linear way to $\psi = 0.8$ by 1985 so that the rate of work stoppages declines by about 80 percent and stays roughly constant afterwards. This decline is shown in the left panel of the graph below.

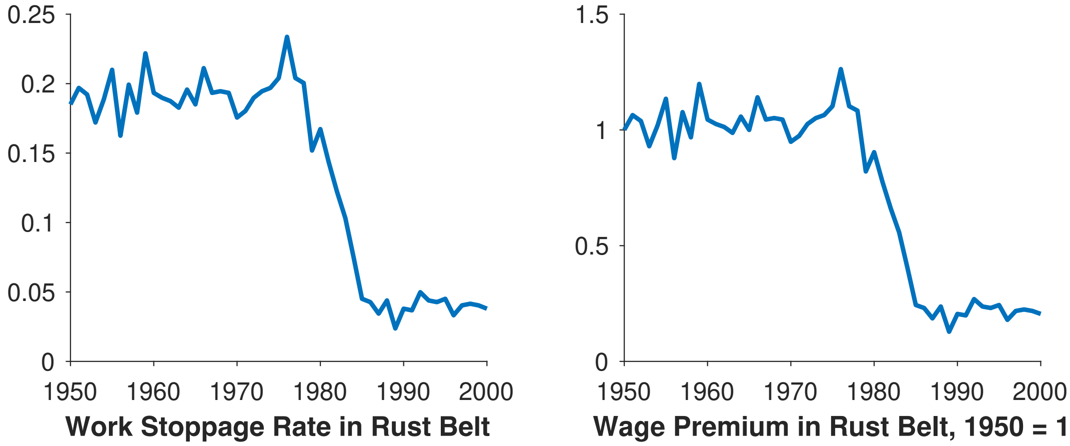

Figure A.2: Labor Conflict over Time

The right panel plots an index of the wage premium in the Rust Belt, computed as the sum of all union rents. This wage premium mechanically varies one-for-one with the work stoppage rate and therefore also falls by around 80 percent as ψ increases.

Like the model in sections 3 and 4, a Card (1990)-style bargaining model requires some exogenous change in the value of a parameter in order to match the variation in the frequency of strikes and in the magnitude of the wage premium across regions and over time. In the benchmark model, the union's bargaining power ϕ generates the critical exogenous variation while the fraction of "move first" firms – denoted ψ – in each region plays the corresponding role here.

One significant shortcoming of this alternative labor-management bargaining model is the counterfactual endogenous strike duration. In the event of no agreement between the firm and the union, a strike lasts for one full model period, which we set to be a year. In the data, however, strikes last 44 days (or 0.12 years), on average. In theory, this can be addressed by shortening a model period to $\frac{1}{8}^{\text{th}}$ of the current length in order to match the strike duration in the data. In terms of the model parameterization, however, this requires an adjustment of the strike probability per model period to match the annual work stoppage rate of 19.2 percent but gives rise to a number of quantitative challenges since most of our remaining data are annual.

G. Diffusion of Labor Conflict Beyond Rust Belt

The Taft-Hartley Act of 1947 facilitated the introduction of "right-to-work" legislation and in the wake of its adoption several states dropped the union membership as a requirement for employment at a unionized facility. What are the implications of a counterfactual scenario where the Taft-Hartley Act is never adopted? In particular, what would have happened to the Rust Belt's share of manufacturing and the labor's income share in U.S. manufacturing if the bargaining power of unions outside the Rust Belt gradually increased over time?

We can simulate such a scenario by increasing the value of ϕ_S in model. In Figure G, ϕ_S increases from 0.02 in 1950 (the calibrated value in section 5) to 0.22 in 2000, which is 50 percent of the calibrated value for ϕ_R. We formalize this diffusion process using the logit function shown in Figure G.

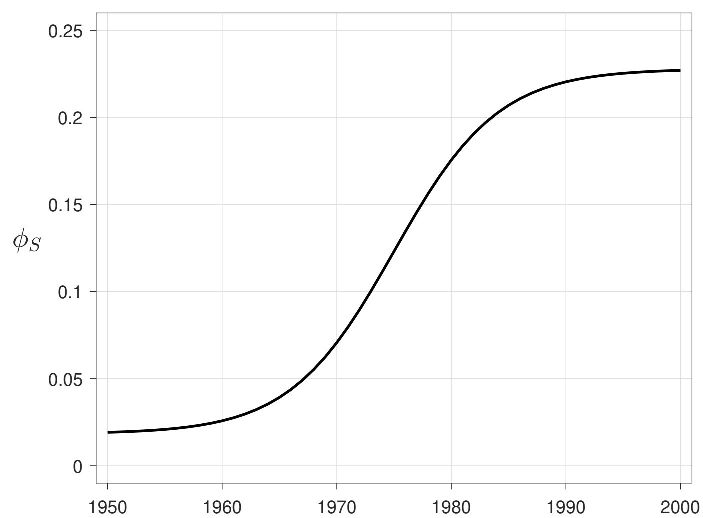

Figure A.3: Counterfactual Path of ϕ_S

Figure G plots the evolution of the Rust Belt's share of employment over time. In this counterfactual simulation, the employment share still declines substantially between 1950 and 2000. This counterintuitive result is driven by increased "stockpiling" of labor by Rest-of-the-Country firms. As these firms are bargaining with ever-stronger unions, they start to stockpile additional workers in order to limit the output losses in the event of a strike where production idles for a fraction $1 - \kappa$ of time. This partially offsets the effects associated with a narrower investment gap as ϕ_S approaches $\frac{1}{2}\phi_R$ and, quantitatively, the Rust Belt's employment losses are similar to those in our benchmark calibration.

Moreover, the labor share of manufacturing counterfactually rises from 71 percent to 74

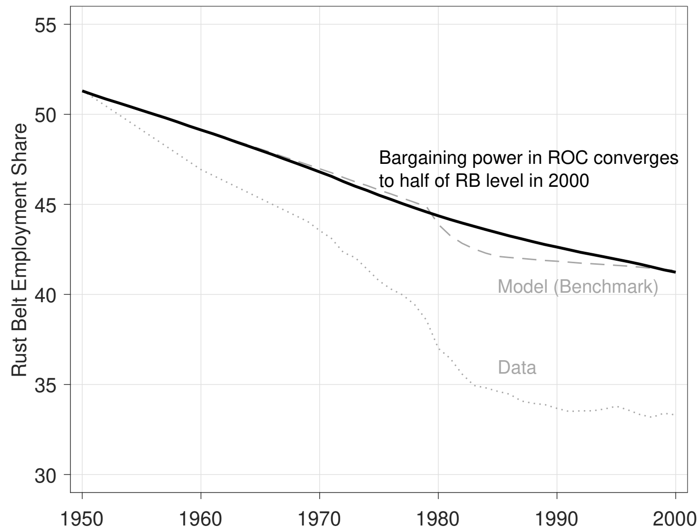

Figure A.4: Employment Share of Rust Belt

percent between 1950 and 2000 (see Figure G).

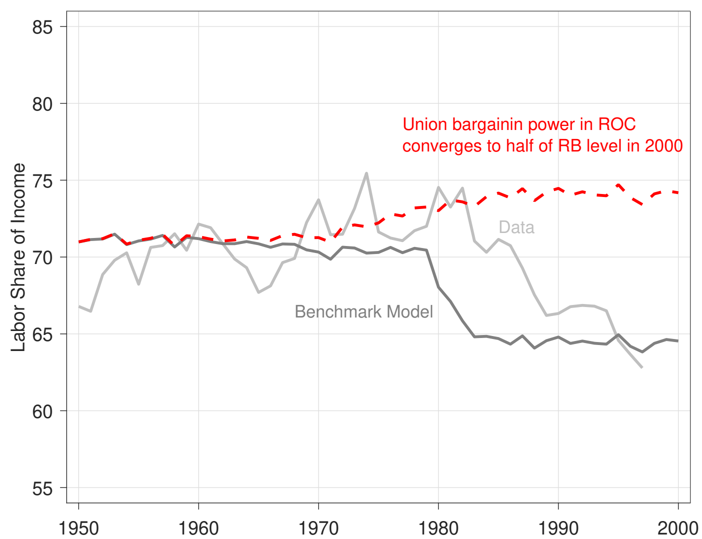

Figure A.5: Labor's Share of Income in Manufacturing

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