Labor Market Conflict and the Decline of the Rust Belt

Simeon Alder
UW Madison

David Lagakos
UCSD and NBER

Lee Ohanian
UCLA and NBER

April 9, 2018

Abstract

No region of the United States fared worse over the postwar period than the "Rust Belt," the heavy manufacturing region bordering the Great Lakes. This paper hypothesizes that the Rust Belt declined in large part due to the persistent labor market conflict which was prevalent throughout the Rust Belt's main industries. We formalize this thesis in a two-region dynamic general equilibrium model in which labor market conflict leads to a hold-up problem in the Rust Belt that reduces investment and productivity growth and leads employment to move from the Rust Belt to the rest of the country. Quantitatively, the model accounts for much of the large secular decline in the Rust Belt's employment share before the 1980s, and its relative stabilization since then, once labor conflict decreased. Consistent with our theory, empirical evidence at the industry-state level shows that more labor conflict, proxied by rates of major work stoppages, is associated with lower employment growth since 1950.

Email: sdalder@wisc.edu, lagakos@ucsd.edu, ohanian@econ.ucla.edu. A previous version of this paper circulated under the title "The Decline of the U.S. Rust Belt: A Macroeconomic Analysis." We thank Ufuk Akcigit, David Autor, Marco Bassetto, Prashant Bharadwaj, Jeffrey Campbell, Jesus Fernandez-Villaverde, Pablo Fajgelbaum, Jeremy Greenwood, Berthold Herrendorf, Tom Holmes, Alejandro Justiniano, Joe Kaboski, Thomas Klier, Michael Peters, Andrea Pozzi, Ed Prescott, Andres Rodriguez-Clare, Leena Rudanko, Jim Schmitz, Todd Schoellman, Marcelo Veracierto, Fabrizio Zilibotti and seminar participants at numerous institutions for comments. We thank Glenn Farley, Caleb Johnson, Patrick Kiernan, Alejandro Nakab, and Jaeyoung Jang for excellent research assistance. All potential errors are ours.

1. Introduction

No region of the United States fared worse over the postwar period than the "Rust Belt," the heavy manufacturing region bordering the Great Lakes. From 1950 to 2000, the Rust Belt's share of U.S. manufacturing employment fell from more than one-half to around one-third, and its share of aggregate employment dropped by a similar magnitude.[1]

This paper develops and quantitatively analyzes a theory of the Rust Belt's economic decline based on the labor market conflict, with chronic strike threats, that dominated most of the Rust Belt's main industries. This theory is motivated by four observations that we document in detail below. One is that Rust Belt wages – even after controlling for observables – were higher than wages in the rest of the country between 1950 and 1980. The second is that productivity growth was relatively low in the Rust Belt between 1950 and 1980. The third is that relations between Rust Belt unions and management were highly conflicted between 1950 and 1980, with strike threats constantly looming over collective bargaining agreements. The fourth observation is that all of these patterns shifted significantly after 1980: the Rust Belt wage premium declined significantly, its productivity growth accelerated, and its labor relations became less conflicted and more cooperative.

We develop a general equilibrium model of the U.S. economy with two regions, the Rust Belt and the Rest of the Country (ROC), to assess how labor market conflict affected Rust Belt economic activity between 1950 and 2000. The two regions differ in the extent of product-market and labor-market competition. Labor markets in the Rust Belt region are tailored to capture the highly conflicted labor relations of Rust Belt unions and firms. To integrate the importance of the strike threat into the analysis, the model's Rust Belt labor market features a hold-up problem in which Rust Belt unions and firms bargain over industry rents after Rust Belt firms have made investments, and in which Rust Belt unions use the strike threat to capture some of the returns from investment. This hold-up problem acts as a tax on investment, and provides Rust Belt union members with higher wages than in the rest of the country. Moreover, this de facto investment tax leads to lower investment by Rust Belt firms relative to ROC firms that operate in competitive labor markets. Lower investment in the Rust Belt leads to relatively low productivity growth, and a shift in labor from the Rust Belt to the ROC.

In product markets, the model captures the role of competition from abroad using simple Ricardian trade forces. The final consumption good is produced using an Armington aggregator over foreign and domestic varieties, which are imperfect substitutes. International trade is subject to iceberg trade costs, which may change over time. We assume two layers of aggregation over foreign and

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[1] We define the Rust Belt to be the states of Illinois, Indiana, Michigan, New York, Ohio, Pennsylvania, West Virginia and Wisconsin. We discuss our data in detail in Section 2.

domestic varieties following Atkeson and Burstein (2008) and Edmond, Midrigan, and Xu (2015), and allow the productivity of Rust Belt firms to be different from those of the rest of the country and abroad. Thus, if the foreign sector has a comparative advantage in varieties that the Rust Belt produces, then a fall in trade costs will lower the Rust Belt's share of output and employment.

The focus of our model on non-competitive labor markets builds on a growing literature that connects lack of competition with low productivity growth (see e.g. Acemoglu, Akcigit, Bloom, and Kerr, 2013; Pavcnik, 2002; Aghion, Bloom, Blundell, Griffith, and Howitt, 2005; Cole, Ohanian, Riascos, and Schmitz Jr., 2005; Schmitz, 2005; Holmes and Schmitz, 2010; Bloom, Draca, and Van Reenen, 2016; Syverson, 2011; Peters, 2013), though our emphasis on hold-up has not received much prior attention in this literature. Our model's integration of depressed productivity growth with regional decline is related to models of structural change, in which differential employment dynamics and differential sectoral productivity growth go hand-in-hand (see e.g. Ngai and Pissarides, 2007; Buera and Kaboski, 2009; Herrendorf, Rogerson, and Valentinyi, 2014).

We use the model to quantify how much of the Rust Belt's employment-share decline can be accounted for by the two channels of competition. To do so, we discipline the extent of union power in labor markets by the Rust Belt wage premia. We also provide direct evidence that these wage premia likely reflected rents, rather than a higher cost of living or higher unmeasured worker ability. We govern the extent of foreign competition by the import shares in the United States as a whole and in the automobile and steel industries, which were concentrated in the Rust Belt. We show that import shares were low until around 1980, and then increased substantially afterward, particularly in automobiles and steel.

We then calculate the equilibrium of the model from 1950 through 2000, in which investment, productivity growth, and employment shares evolve endogenously in the two regions. The model predicts a steady secular decline in the Rust Belt's employment share until 1980, a one-time drop in 1980, and a modest increase afterwards. The model's overall decline is 9.8 percentage points, compared to 18 percent points in the data, and hence the model accounts for around 54 percent of the Rust Belt's decline. The model is also consistent with the timing of the Rust Belt's decline, which mostly comes before 1980, has a one-time drop around 1980, and then is largely flat afterwards. Finally, the model is consistent with the Rust Belt's productivity growth. We document labor productivity growth was lower on average in the Rust Belt's main industries than in the other industries before the 1980s, and that productivity growth rose dramatically in many Rust Belt industries since then. This is what our model predicts qualitatively, though the model under-predicts the increase in Rust Belt productivity growth after 1980.

To decompose the importance of the theory we conduct two counterfactual experiments using the model. First, we recompute the model's predictions assuming that trade costs did not fall in the

1980s, as they did in the data, but keeping the union hold-up problem. Second, we simulate the model assuming away the union hold-up problem, but keeping the decline in trade costs of the 1980s. We find that it in the latter case, the timing of the Rust Belt's decline is inconsistent with the data, with almost all of the decline happening counterfactually after 1980. In contrast, in the counterfactual with hold-up but without the trade cost reduction, the timing of the decline is largely before 1980, as in the data. This latter counterfactual also generates a larger decline than does the former, though not as large as in the data, of around 7.6 percentage points, or 42 percent of the observed decline.

We conclude by presenting evidence at the state-industry level on measures of labor market conflict and employment growth from 1950 to 2000. We first consider work stoppages as a measure of labor conflict, and find that more work stoppages per year is associated with significantly lower employment growth, even after including industry fixed effects and controls for state climate and initial industry concentration and population. We then consider unionization rates from 1973 to 1979, which is the earliest period our data allow, and find a similar negative relationship between unionization and employment growth. Finally, to address potential concerns of reverse causality, running from industry employment decline to labor conflict, we consider a measure of conflict that long pre-dated post-war employment growth: strikes occurring between 1927 and 1934, for which the BLS collected historical evidence. These data show that strikes from 1927-1934 were significantly negatively associated with employment growth from 1950 to 2000, pointing to a role for conflict in leading to poor employment outcomes, rather than the other way around. To the extent that work stoppages, unionization rates and strikes reflect labor market conflict, these state-industry data provide further disaggregated evidence that conflicted labor markets played a role in postwar regional employment dynamics.

Few prior papers have attempted to explain the root causes of the Rust Belt's decline. The only other theory of which we are aware is that of Yoon (Forthcoming), who argues, in contrast to our work, that the Rust Belt's decline was due in large part to rapid technological change in manufacturing. Some other papers are implicitly related to the Rust Belt decline. Glaeser and Ponzetto (2007) theorize that the decline in transportation costs over the postwar period may have caused the declines of U.S. regions whose industries depend on being close to their customers, of which the Rust Belt is arguably a good example. Similarly, Desmet and Rossi-Hansberg (2009) argue that the declining importance of knowledge spillovers led formerly concentrated industries to spread out through space, and Duranton and Puga (2009) emphasize the declining costs of communication. None of these theories emphasize labor market conflict, however, as we do. A number of papers have studied the macroeconomic consequences of unionization, (see e.g. Borjas and Ramey, 1995; Bridgman, 2015; Taschereau-Dumouchel, 2015; Dinlersoz and Greenwood, 2012; Acikgoz and

Kaymak, 2014), though none have related labor conflict to the decline of the Rust Belt per se.[2]

The rest of the paper is organized as follows. Section 2 details the facts regarding the Rust Belt's employment-share decline, the conflict and wage premium in its manufacturing industries, and its lower productivity growth relative to the rest of the country. Section 3 presents the model economy. Section 4 presents the quantitative analysis. Section 5 presents supporting evidence on state-industry labor conflict measures and employment growth outcomes. Section 6 concludes.

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[2] Feyrer, Sacerdote, and Stern (2007) and Kahn (1999) study the labor-market and environmental consequences of the Rust Belt's decline, respectively, but do not attempt to explain the underlying causes of the decline.

2. Decline of the Rust Belt: The Facts

In this section, we document a set of facts characterizing the Rust Belt's decline. We begin with the decline itself, by showing that the Rust Belt's share of aggregate and manufacturing employment declined secularly from 1950 to 2000. We then show that manufacturing industries in the Rust Belt were characterized by higher rates of unionization and work stoppages than service industries in the Rust Belt or industries in the rest of the country. Similarly, manufacturing industries in the Rust Belt paid substantially wage premiums over the same period. We then show that labor productivity growth in manufacturing industries located predominantly in the Rust Belt was lower than average. Finally, we show that all these empirical patterns changed significantly in the 1980s.

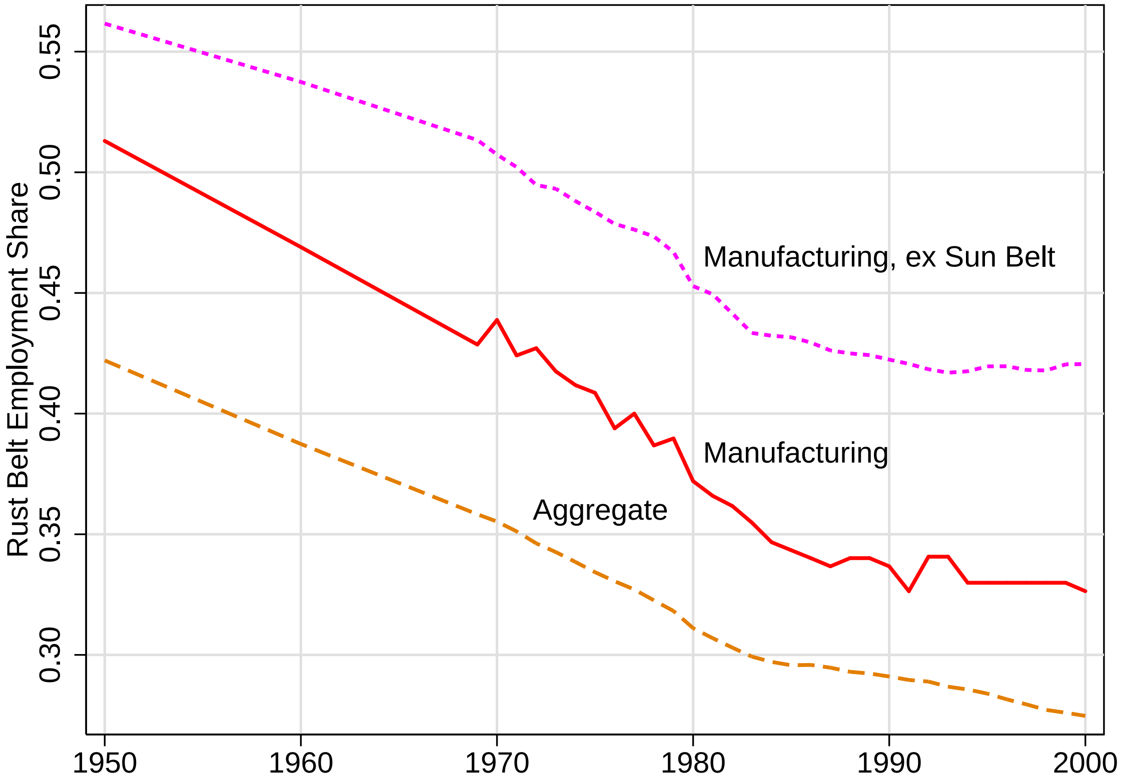
2.1. Decline of the Rust Belt's Employment Share

We begin with the basic fact that motivates this paper: the Rust Belt's share of employment decreased secularly over the postwar period. We define the Rust Belt as the states of Illinois, Indiana, Michigan, New York, Ohio, Pennsylvania, West Virginia and Wisconsin. This definition encompasses the heavy manufacturing area bordering the Great Lakes, and is similar to previous uses of the term (see, e.g., Blanchard and Katz (1992), Feyrer, Sacerdote, and Stern (2007) and the references therein). Our main data are the U.S. Censuses of 1950 through 2000, available through the Integrated Public Use Microdata Series (IPUMS), and we focus on private-sector wage workers. See Appendix A for a more detailed description of our data.

Figure 1 plots the Rust Belt's share of employment from 1950 through 2000 by three different metrics. The first is the aggregate employment share (dashed orange), which began at 43 percent in 1950 and declined to 27 percent in 2000. Note that the decline started right in 1950, which is earlier than commonly thought, and was most pronounced in the period from 1950 to around 1980. The second metric is the share of U.S. manufacturing employment located in the Rust Belt (solid red), which began at 51 percent in 1950 and declined to 33 percent by 2000. The fact that the Rust Belt's share of manufacturing employment dropped so much indicates that the decline is not just a structural shift out of manufacturing. That is, even though manufacturing was declining relative to services in the aggregate, employment *within the manufacturing sector* shifted from the Rust Belt to the rest of the country. Furthermore, this pattern holds even within more narrowly defined industries. For example the Rust Belt's share of U.S. employment in steel, autos and rubber tire manufacturing fell from 75 percent in 1950 to 55 percent in 2000.

The third metric we consider is the Rust Belt's share of U.S. manufacturing employment excluding the "Sun Belt" states of Arizona, California, Florida, New Mexico and Nevada (Blanchard and Katz, 1992). The share of manufacturing employment in states other than the Sun Belt states

Figure 1: The Rust Belt's Employment Share



(dotted purple) was 56 percent in 1950 and 42 percent in 2000. This shows that the Rust Belt's decline is not accounted for by movements, possibly related to weather, of workers to the Sun Belt. In contrast, the Rust Belt's employment share declined substantially even after excluding these states. This is consistent with the work of Holmes (1998), who studies U.S. counties within 25 miles of the border between right-to-work states (most of which are outside the Rust Belt) and other states, and finds much faster employment growth in the right-to-work state counties next to the border than in counties right across the state border.[3]

More broadly, no region of the United States declined as much as the Rust Belt. Of the seven states with the largest drops in their share of aggregate employment between 1950 and 2000, six are in the Rust Belt. Of the seven states with the sharpest decline in manufacturing employment, five are in the Rust Belt. Finally, taken individually, every single Rust Belt state experienced a substantial fall in aggregate and manufacturing employment relative to the rest of the country.

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[3] It is also consistent with the findings of Rappaport (2007), who concludes that weather-related migration out of the states in the Rust Belt played only a modest role in their declining population share. Other areas in the midwest, and New England, for example, have similar weather but had much smaller population declines. We revisit the role of climate in the Rust Belt's decline in Section 5.

2.2. Unionization and Labor Conflict in the Rust Belt

Next, we present patterns of unionization and labor conflict in the United States, and show that the highest rates of union membership and major work stoppages were in manufacturing industries located in the Rust Belt. We begin with unionization, using CPS data from 1973 to 1980, which are the earliest nationally representative unionization data (of which we are aware) that can be disaggregated by region and industry.

Table 1: Unionization and Major Work Stoppage Rates by Region and Industry

Panel A: Unionization Rates

	Manufacturing	Services	Overall
Rust Belt	48.1	22.5	30.9
Rest of Country	28.4	14.4	18.1

Panel B: Major Work Stoppages Rates

	Manufacturing	Services	Overall
Rust Belt	19.2	3.2	9.7
Rest of Country	2.7	0.9	1.6

Note: Panel A reports the unionization rate by region and broad industry. The data cover the years 1973 to 1980 and come from the CPS. Panel B reports the average percent of years in which there was a major work stoppage, defined as a work stoppage affecting 1,000 workers or more, by region and broad industry. The average is taken across all 3-digit manufacturing and service industries. The data cover the years 1958 to 1977 and come from the BLS.

Table 1, Panel A, reports the unionization rate by broad industry and region for the years 1973 to 1980. The highest unionization rate was in Rust Belt manufacturing industries, where 48.1 percent of workers were union members. Manufacturing workers in the rest of the country were next at 28.4 percent, followed by service workers in the Rust Belt (22.5 percent) and service workers in the rest of the country (14.4 percent). To be sure, the finding that the most unionized industries in the United States were manufacturing industries in the Rust Belt is not new to our paper, and is in fact consistent with numerous previous studies of collective bargaining in the United States (see e.g. Goldfield, 1987; Kochan, Katz, and McKersie, 1994).

We next turn to data on work stoppages, which are a proxy for labor conflict. In particularly, we draw on work stoppage data collected by the BLS in a consistent way from 1958 to 1977. The data include the industry, state and number of workers involved in each work stoppage. We define a major work stoppage to be one that affects 1,000 or more workers, which is a cutoff used by the BLS in their aggregate statistics. A work stoppage could be initiated by workers, in the form of a strike, or by management, in the form of a lockout. In either case, it is clear that a work stoppage is a symptom of conflict between workers and management.

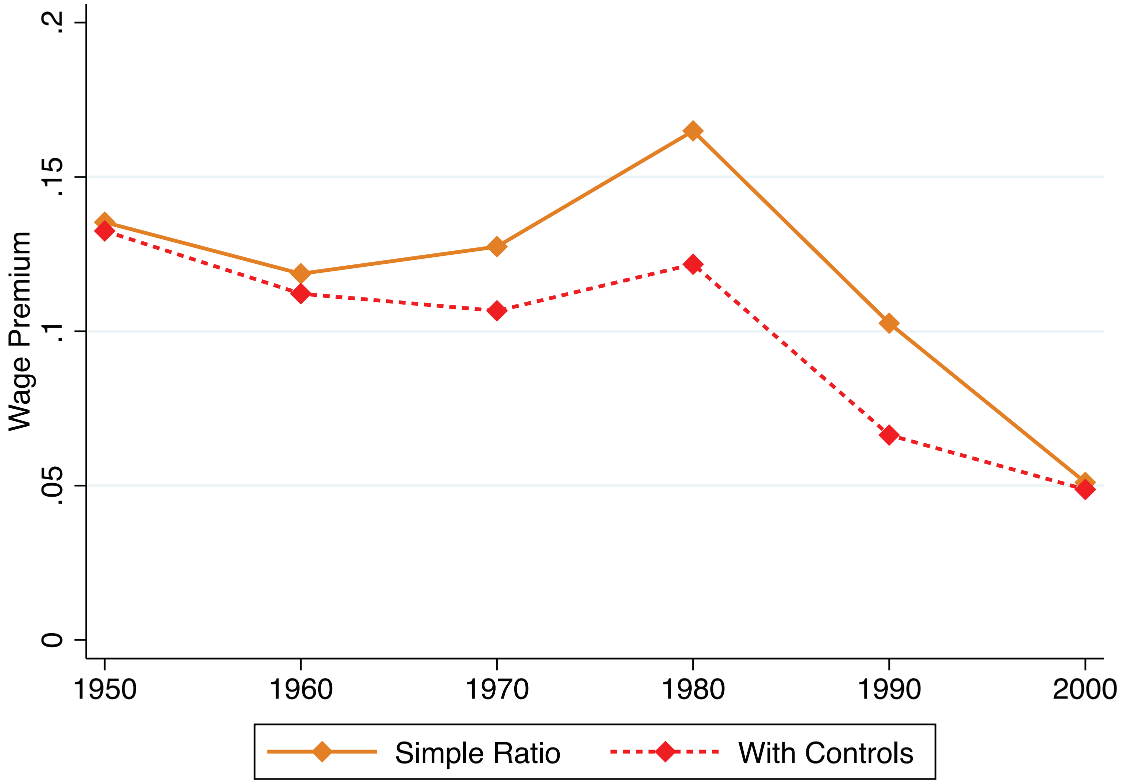
Table 1, Panel B, computes the rates of major work stoppages by broad industry in the Rust Belt and the rest of the United States, measured as the percent of years involving a major work stoppage, on average, across three-digit industries. As the table shows, by far the highest rates of work stoppages were in the Rust Belt manufacturing industries, where, on average, 19.2 percent of years involved a work stoppage. This rate of roughly one strike every five years is consistent with historical studies of the Rust Belt's main manufacturing industries, such as Steel and Autos (see e.g. Richter, 2003). Far lower were rates of major work stoppages in Rust Belt services, at 3.2 percent per year, manufacturing in the rest of the country, at 2.7 percent per year, and services in the rest of the country, at just 0.9 percent per year.

While the general pattern of unionization by region and industry is similar to that of work stoppages, it is worth noting that work stoppage rates are far higher in Rust Belt manufacturing than in other regions or industries, while unionization rates are only modestly higher in the Rust Belt manufacturing industries. Specifically, within manufacturing, unionization rates were about twice as high in the Rust Belt as elsewhere, whereas rates of major work stoppages were about seven times as high. In other words, unions in the Rust Belt appear to have been more prone to conflict than other unions, and in particular those in manufacturing industries outside of the Rust Belt. The fact that the Rust Belt manufacturing industries were the most conflicted in the United States is corroborated by numerous historical studies (see e.g. Lodge, 1986; Nelson, 1996; Lam, Norsworthy, and Zabala, 1991). Moreover, it is widely agreed that the conflict began with the violent union organizations of these industries in the 1930s (Kennedy, 1999; Millis and Brown, 1950). For example, a 1982 National Academy of Sciences project on the U.S. auto industry argues that the violent union organizations and sit-down strikes of the late 1930s defined an "adversarial and bitter relationship between labor and management" (Clark, 1982). Barnard (2004), Katz (1985), Kochan, Katz, and McKersie (1994), Kuhn (1961), Serrin (1973) and Strohmeyer (1986) also describe how the organization conflicts of the 1930s and 1940s evolved into chronically conflicted relations in which the strike threat dominated labor negotiations in many Rust Belt industries after World War II.

2.3. Wage Premia in Rust Belt Manufacturing

This section turns to data on relative wages of manufacturing workers in the Rust Belt. We focus on manufacturing workers because the evidence in the previous section points to conflict as being

Figure 2: Wage Premium Earned by Rust Belt Manufacturing Workers



primarily within the Rust Belt's manufacturing sector. Figure 2 plots two different measures of the wage premium earned by manufacturing workers in the Rust Belt relative to manufacturing workers in the rest of the country. The first is the sample ratio of average manufacturing wages (minus one), plotted as a solid orange line. This simple wage premium started out at 13 percent in 1950, stayed between 12 and 16 percent through 1980, and then fall to 5 percent by 2000.

One natural explanation for the positive simple wage premium is that Rust Belt workers were on average better educated or more experienced than other manufacturing workers. To address this possibility, we compute the residual wage premium after controlling for education, age, age squared and a sex dummy. This wage premium with controls is plotted as the dashed red line in Figure 2. It started out at 13 percent in 1950, stayed between 11 and 13 percent through 1980, and then fell to 6 percent in 1990 and around 5 percent in 2000. Thus, even with these controls, manufacturing workers in the Rust Belt earned substantial wage premia over this period, at least until 1980.[4]

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[4] A related possible alternative interpretation is that workers in the Rust Belt were more productive on average, even after controlling for schooling, experience, sex and race, at least in the period up until the 1980s. As one way of evaluating this possibility, we consider data on wage losses of displaced workers from the Rust Belt compared to the rest of the country. The data are available as part of the Displaced Workers supplement to the Current Population

Another simple potential explanation of these patterns is that the cost of living was higher in the Rust Belt than elsewhere. While time series on regional costs of living in the United States do not exist, the BLS did estimate costs of living in a sample of 39 cities in one year, 1966, in the middle of our time period (U.S. Bureau of Labor Statistics, 1967). When comparing the average cost of living in Rust Belt cities to the average for the rest of the country, we find that the difference is small in magnitude, with the Rust Belt cities being at most two percent more expensive, and statistically insignificant (see Appendix A). These data therefore cast doubt on the interpretation of the wage premium as a payment for higher cost of living. Relatedly, the premium earned by manufacturing workers in the Rust Belt was not shared by service workers located in the Rust Belt; in 1950, for example, these non-manufacturing workers earned 0.97 times the national average wage, and substantially less than Rust Belt manufacturing workers.

What else could account for this wage premium? There is a strong case, based on theory and evidence, that the high unionization and work stoppage rates presented in the previous subsection are related to the wage premium earned by Rust Belt manufacturing workers. As described in Farber (1986)'s survey chapter on union behavior, the standard view of unions is that of an organization that bargains over industry rents in the form of wage premia, and that rations scarce, high-paying union jobs in order to preserve those premia. Models of union labor markets and job rationing are the focus of the large literature on insider-outsider models of unions developed by Lindbeck and Snower (1988), Blanchard and Summers (1986) and Cole and Ohanian (2004), in which unions restrict their membership to maximize rents per worker. These studies cite considerable evidence of union rents and union job rationing. More broadly, Dickens and Lang (1985, 1988) present evidence from CPS data that supports job rationing. Using CPS data from the early 1980s, they find a significant union wage premium after controlling for race, marital status, education, experience. Moreover, they find evidence that jobs were rationed among white males.

Meier and Rudwick (1979) and Hinshaw (2002) provide detailed studies of the U.S. auto and steel industries, which were concentrated in the Rust Belt, and confirm Dickens and Lang (1985, 1988)'s finding that an important component of job rationing was sharply restricting union jobs offered to women and minorities. Another mechanism in rationing union jobs was nepotism in new hiring. Kupfberg (1999) describes discrimination lawsuits in which unions de facto discriminated against minority candidates by accepting new members who were referred by existing union workers, typically through family or friendship connections. Many lawsuits were in the auto and steel industries.

Survey (CPS) of 1986, which asked follow-up questions of each worker that was displaced from a job between 1981 and 1986. These data are from right at the end of the period of high wage premia, which is not ideal, though they are the earliest data available. We find that Rust Belt workers lost 51.1 percent of their pre-displacement wages on average after a plant closing, compared to 35.5 percent for workers in the rest of the country. The difference is statistically significant at the one-percent level. If anything, this points to more rents among Rust Belt workers rather than more productive workers there. See Appendix A.

These studies draw a direct link between the high work stoppage rates, high unionization rates and high relative wages of manufacturing workers in the Rust Belt.[5]

2.4. Low Productivity Growth in Rust Belt Manufacturing Industries

The next fact we document is that labor productivity growth was lower in manufacturing industries prevalent in the Rust Belt than in other U.S. manufacturing industries, at least until the 1980s. The main challenge we face is that direct measures of productivity growth by region are not available for many industries. 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 define Rust Belt intensive industries, 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 2 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 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).[6]

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[5] A natural question is whether firms tried to escape labor market conflict by substituting other inputs for labor or relocating their production. In fact, many firms in the Rust Belt did try to escape labor market conflict by substituting capital for labor (see e.g. Serrin, 1973; Meyer, 2004). However, organized labor generally resisted these attempts, and explicitly limited capital-labor substitution as part of their collective bargaining agreements (Strohmeyer, 1986; Rose, 1998; Barnard, 2004; Steigerwald, 2010). Firms did also attempt to escape conflict by re-locating their production outside of the Rust Belt. For example, the auto industry developed a relocation plan that was known as the "Southern Strategy" in the 1960s and 1970s, which involved moving auto production to southern states where unions were less prevalent. However, this approach did not achieve what management had hoped. Nelson describes that "the UAW was able to respond (to the Southern Strategy) by maintaining virtually 100 percent organization of production workers in all production facilities" (see Nelson (1996), p 165).

[6] In Appendix Table A.5 we show that our results hold for a broader definition of Rust Belt industries. We also find lower productivity growth rates in Rust Belt industries between 1958 to 1985 when using double-deflated value added per worker or TFP as our measure of productivity. A detailed description of the NBER CES data, and the data themselves, are available here: http://www.nber.org/nberces/.

Table 2: Labor Productivity Growth in Rust Belt Industries

	Annualized Growth Rate, %		
	1958-1985	1985-1997	1958-1997
Blast furnaces, steelworks, mills	0.9	7.6	2.8
Engines and turbines	2.3	2.9	2.5
Iron and steel foundries	1.5	2.3	1.7
Metal forgings and stampings	1.5	2.8	1.9
Metalworking machinery	0.9	3.5	1.6
Motor vehicles and motor vehicle equipment	2.5	3.8	2.9
Photographic equipment and supplies	4.7	5.1	4.9
Railroad locomotives and equipment	1.6	3.1	2.0
Screw machine products	1.2	1.1	1.2
Rust Belt weighted average	2.0	4.2	2.6
Manufacturing weighted average	2.6	3.2	2.8

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.

One potential limitation of the productivity measures of Table 2 is that they do not directly measure productivity by region. However, these productivity patterns are consistent with a study that does measure productivity by region directly, using plant-level data. For the steel industry, Collard-Wexler and De Loecker (2015) measure labor productivity growth and TFP growth by two broad types of producers: the vertically integrated mills, most of which were in the Rust Belt, and the minimills, most of which were in the South. They find that for the vertically integrated mills, TFP growth was very low from 1963 to 1982 and, in fact, negative for much of the period. In contrast, they report robust TFP growth post-1982 in the vertically integrated mills: TFP improved by 11 percent from 1982 to 1987 and by 16 percent between 1992 and 1997.

2.5. Changes of the 1980s

The four facts described above - the substantial decline in the Rust Belt's employment share, its high rates of conflict in its manufacturing industries, its manufacturing wage premium, and its low manufacturing productivity growth - changed significantly in the 1980s. Figure 1 shows that the decline in the Rust Belt's employment share slowed after 1985. Specifically, the Rust Belt's share of aggregate employment declined by about 12 percentage points between 1950 and 1985, but declined only 3 percentage points afterwards. Similarly, the Rust Belt's manufacturing employment share declined by about 16 percentage points between 1950 and 1985, but declined by only 2 additional percentage points from 1985 to 2000.

Labor relations in the Rust Belt began to change in the 1980s. A large literature describes how Rust Belt union-management relationships began to shift to more cooperation and efficiency around this time, with a very large decrease in the number of strikes, and the use of strike threats (see Beik (2005), Katz (1985) and Kochan, Katz, and McKersie (1994)). The change in labor relations is seen clearly in Figure 3, which shows the number of major strikes per year (involving at least one thousand workers) from the end of WWII through 2000. The figure shows that the number of large strikes declined remarkably around the early 1980s, from several hundred per year before to less than fifty afterwards. Many studies have analyzed how union bargaining power declined around this time, and much of the literature cites Reagan's 1981 decision to fire striking unionized federal air traffic controllers as a key factor (see McCartin (1986) and Cloud (2011) and the references therein). Academic studies, as well as the views of industry participants, conclude that the firing of the air traffic controllers and the decertification of their union led to much wider use of permanent replacement workers during strikes, which in turn reduced union bargaining power and the effectiveness of the strike threat.[7]

While data on conflict by region and industry are not available after 1980, the fact that the bast majority of work stoppages were in the Rust Belt manufacturing industries before 1980 suggests that the largest decline in work stoppage rates must have been in Rust Belt manufacturing. Direct evidence also suggests that this is the case. For example, Clark (1982), Hoerr (1988), Kochan, Katz, and McKersie (1994) and Strohmeyer (1986) describe how management and unions in autos and steel changed their bargaining relationships in the 1980s, including changing work rules that impeded productivity growth, in order to increase the competitiveness of their industries. Similarly, the United Steelworkers President Lloyd McBride described steel industry labor relations in 1982

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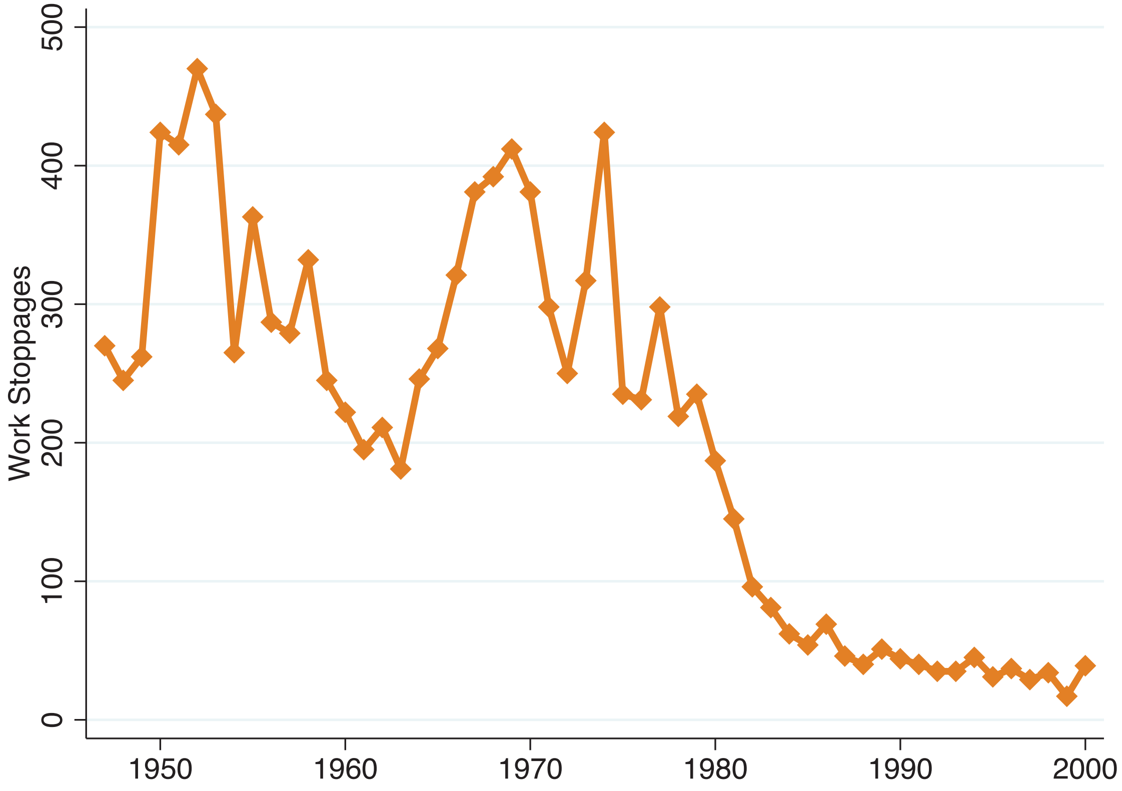
[7] Relatedly, Leroy (1987) found that firms hired permanent replacement workers during strikes much more frequently in the 1980s than before. Cramton and Tracy (1998) found that the increased use of replacement workers in the 1980s relative to the 1970s significantly affected unions' decisions to strike, and that this factor can account for about half of the decline in strike activity that occurred after the 1970s. Cramton and Tracy (1998) discuss how The AFL-CIO stated in their 1986 training manual *The Inside Game: Winning With Workplace Strategies* that the increased use of replacement workers had substantially reduced the usefulness of the strike as a bargaining tactic. The training manual notes: "When an employer begins trying to play by the "new rules" and actually force a strike, staying on the job and working from the inside may be more appropriate" (page 5, emphasis in original). The effect of permanent replacement workers on the effectiveness of the strike threat is also held more broadly. A 1990 GAO survey of both unions, and employers with unionized employees, found that 100 percent of union leaders agreed that the use of permanent replacement workers was much higher in the 1980s compared to the 1970s, and 80 percent of employers agreed with that statement (United States General Accounting Office, 1990).

Figure 3: Major Work Stoppages in the United States



as follows: "The problems in our industry are mutual between management and labor relations, and have to be solved. Thus far, we have failed to do this" (see Hoerr (1988), page 19).

Consistent with the theory that the Rust Belt's wage premia were related to their labor conflict, the decline in worker bargaining power coincides with the declining wage premium. As shown in Figure 2, the wage premium we estimate for Rust Belt manufacturing workers fell from 13 percent in 1950 to around 5 percent by 2000. Appendix Table A.4 shows that the Rust Belt wage premium falls after 1980 when including all workers, when restricting to full time workers, and when including dummies for more detailed race and educational attainment categories.

Turning to productivity, Table 2 shows the Rust Belt productivity pickup 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. Their average growth rate was 2.0 percent year from 1958 to 1985, but rose 4.2 percent per year after 1985. We also find that investment rates increased substantially in most Rust Belt industries in the 1980s, rising from an average of 4.8 percent to 7.7 percent per year. Appendix

Table A.5 shows that productivity increases occurred, on average, under a broader definition of Rust Belt industries.

3. Model of Rust Belt's Decline

This section develops a two-region general equilibrium model of the United States to quantitatively assess how labor conflict in the Rust Belt's manufacturing sector affected the evolution of the Rust Belt's share of U.S. employment. The model is tailored to capture several features of the Rust Belt economy, including the chronically conflicted and inefficient labor relations between manufacturing firms and unions described in Section 2, and the relatively low level of productivity growth by the Rust Belt manufacturing sector.

In the model, the union hold-up problem in the Rust Belt manufacturing sector is the key component that provides the model's link between labor conflict and the endogenous evolution of regional productivity growth and employment shares in U.S. manufacturing. Rust Belt unions bargain with Rust Belt manufacturing firms after firms have already made their investments. Unions are able to raise wages above the competitive wage rate by obtaining some of the returns from those investments through a strike threat. This strike threat is a de facto tax on investment, and thus reduces the incentives for Rust Belt firms to invest. Workers optimally choose their location and sector, given the Rust Belt wage premium, the scarcity of union jobs, and given their union membership status. All other labor markets are competitive and workers employed outside the Rust Belt manufacturing sector are paid the competitive wage w. International trade is included in the model to evaluate the role of imports, particularly the increase in foreign competition starting in the 1980s.

3.1. Regions, Preferences and Technologies

Time is discrete and periods are indexed by t. There is a unit measure of workers with constant elasticity preferences over a final manufactured goods, $C_{m,t}$, and non-tradeable services, $C_{n,t}$. There are two regions, the Rust Belt, R, and the rest of the country (ROC), S, indexed by $\ell \in \{R, S\}$. Manufactured goods can be traded internationally and across regions, while services can only be consumed in the region in which are produced. The workers' preferences are given by:

$$\sum_{t=0}^{\infty} \delta^t \left(\mu (C_{m,t})^{\frac{\theta-1}{\theta}} (1-\mu) (C^{\ell}_{n,t})^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}} \tag{1}$$

where δ is their discount factor, satisfying $0 < \delta < 1$, and θ is the elasticity of substitution between manufactured goods, which we restrict to satisfy $0 < \theta < 1$, meaning that manufacturing and services are gross complements, following the literature on structural change (Herrendorf Handbook chapter). The workers are endowed with one unit of labor each period that they supply inelastically to the labor market.

The local, non-traded service is produced in a competitive market using only labor inputs:

$$Y_{n,t} = Z^{\ell}_{n,t} L^{\ell}_{n,t}, \tag{2}$$

where $Z^{\ell}_{n,t}$ and $L_{n,t}$ are the productivity and labor input of services in region ℓ. The productivities of the service sector grows at the constant exogenous growth rate χ in both regions, so that $Z^{\ell}_{n,t+1} = (1+\chi)Z^{\ell}_{n,t}$ in both $\ell \in \{R,S\}$. Services are produced competitively in both sectors. For expositional purposes, we drop the time subscript t whenever possible from here on.

The final manufactured good can be consumed by workers or used as an input into the firms' innovation technology. It is produced using a continuum of intermediate manufactured goods, indexed by $i \in [0,1]$, and using the technology:

$$Y = \left(\int_0^1 y(i)^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1}}, \tag{3}$$

where $y(i)$ denotes the input quantity from sector i, and σ is the elasticity of substitution between inputs from any two sectors. We assume that $\sigma > 1$, which implies that inputs from any pair of sectors are gross substitutes.

The two regions in the model differ in the set of manufacturing intermediates that they produce. In particular, the sectors indexed by $i \in (0,\lambda]$ are located in the Rust Belt, and those indexed by $i \in (\lambda,1]$ are located in the Rest of the Country. These regions differ in the nature of competition in their labor markets. We describe these differences in market structure shortly.

Similar to the models of Atkeson and Burstein (2008) and Edmond, Midrigan, and Xu (2015), we assume that each of the sectors is populated by a continuum of firms producing differentiated intermediate goods. These domestic firms are indexed by $j \in (0,1)$ and there is an analogous unit measure of foreign firms in each sector i.[8] The output of any sector i is a composite of the domestic and foreign intermediate goods in i:

$$y(i) = \left(\int_0^1 y(i,j)^{\frac{\rho-1}{\rho}} + y^*(i,j)^{\frac{\rho-1}{\rho}} dj \right)^{\frac{\rho}{\rho-1}}, \tag{4}$$

where $y(i,j)$ is domestic intermediate good j in sector i, $y^*(i,j)$ is the corresponding foreign intermediate in the same sector, and ρ is the elasticity of substitution between any two varieties of good i, whether home or foreign. Moreover, we follow Atkeson and Burstein (2008) and Edmond, Midrigan, and Xu (2015) and assume that $\rho > \sigma$, meaning the substitutability between any two

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[8] Note that a domestic producer (i,j) does *not* compete head-to-head with his foreign counterpart. Rather, competition is monopolistic vis-à-vis *all* domestic and foreign producers in industry i.

within-sector intermediates is higher than between a pair of intermediates in two different sectors.

Each good is produced by a single firm using the following linear technology:

$$y(i,j) = z(i,j) \cdot l(i,j), \tag{5}$$

where $z(i,j)$ is the domestic firm's productivity and $l(i,j)$ is the labor input chosen by the firm. Each firm takes its own productivity and the productivities of all other firms in the current period as given. The productivities of domestic manufacturing firms evolve endogenously and we describe this innovation process in section 3.6.

3.2. Foreign Sector and Trade

Let $z^*(i,j)$ denote the productivity of a foreign firm producing intermediate j in sector i. Analogously to production at home, a single firm produces a variety j in sector i abroad using the technology

$$y^*(i,j) = z^*(i,j) \cdot l^*(i,j) \tag{6}$$

Moreover, let Z denote the set of all productivities across all domestic and foreign firms, that is, $Z \equiv \{z(i,j)\}_{i,j=0}^{1} \cup \{z^*(i,j)\}_{i,j=0}^{1}$.

For simplicity, we restrict our attention to symmetric equilibria where domestic productivities are equalized *within* regions and hence take on one of two values, z^R and z^S. Put differently, z^R denotes the productivity of firms that produce intermediate goods in sectors indexed by $i \in (0,\lambda]$, i.e. those in the Rust Belt, and z^S the productivity of those firms in sectors indexed by $i \in (\lambda,1]$. Similarly, foreign productivities are z^{*R} and z^{*S} in regions R and S, respectively. In contrast to the endogenous innovation decisions at home, the productivities of foreign manufacturers evolve exogenously, for simplicity, at rates χ^{*R} and χ^{*S}, so that $z^{*R'} = z^{*R}(1+\chi^{*R})$ and $z^{*S'} = z^{*S}(1+\chi^{*S})$.

All intermediate manufactures can be traded domestically at no cost and internationally at an iceberg-style cost $\tau \geq 1$. This symmetric international trade cost evolves exogenously according to a Markov process, which we describe in section 3.4. Lastly, we require trade to be balanced each period. This simplification enables us to maintain rich features elsewhere in the model without substantively affecting our quantitative findings.

3.3. Labor Markets and the Union

Labor markets differ by region. In the Rust Belt, labor markets in the manufacturing sector are governed by a labor union, while they are perfectly competitive elsewhere. Each worker's status is either "non-union" or "union member". We denote the union status of a given worker by $\upsilon \in \{0,1\}$.

We assume that the cost of moving workers across space is zero. However, only union members can be hired by Rust Belt manufacturers. Non-union workers can work in the either of the two non-traded sectors or in Rest-of-the-Country manufacturing, or they can attempt to get hold of a manufacturing job in the Rust Belt by applying for union membership. Any non-union worker choosing to locate in the Rust Belt faces a (time-varying) probability F of being offered a union card and hence the opportunity to take a union job. The rate F is a function of the state, though we write it as a number here for convenience.[9] If the worker ends up with a union job, she earns the union wage and becomes a union member. With probability $1-F$ she does not find work in Rust Belt manufacturing, remains non-union, and, in addition, incurs a disutility $\bar{u}$ of having queued unsuccessfully.

Union membership is an absorbing status but each period an exogenous fraction ζ of all workers retires and is replaced with an identical fraction of new workers, who enter with non-union status. This parsimonious life-cycle specification of the workforce allows us to specify the workers' location decisions in a convenient way, given that union jobs are rationed.

Let U denote the unionization rate in a particular period, i.e. the measure of unionized workers, and let M be the (endogenous) fraction of non-union workers that choose to locate in the Rust Belt. The law of motion for unionization is given by:

$$U' = (1-\zeta)[U + MF(1-U)], \tag{7}$$

so that next period's unionization rate is the measure of union members who didn't retire plus the measure of (formerly non-union) workers who chose to locate in the Rust Belt, apply for a union card, and was granted membership in the current period.

Non-union workers receive the competitive wage each period, which we normalize to unity. Union workers are paid the competitive wage plus a union rent, which is a share of the profits of manufacturing firms in the Rust Belt. We assume that profits are split each period between each Rust Belt manufacturer and its unionized labor force according to a Nash bargaining protocol, as in the bargaining model of Grout (1984). This assumption provides a simple way of capturing the persistent holdup problem that characterized Rust Belt labor relations for decades. The parameter β is the union's Nash bargaining weight, which evolves exogenously over time according to the Markov process specified in the next section.[10]

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[9] To fix ideas, you can think of the application process as a queuing problem – since union jobs are rationed – with random selection if Rust Belt jobs cannot be filled with current union members. F is the probability of selection and it equals the ratio of open jobs to the length of the queue at the union hall, both of which depend on the state of the economy.

[10] We adopt the Nash Bargaining protocol for simplicity. Alternatively, we consider a dynamic bargaining model along the lines of Cole and Ohanian (2004), in which the union's take-it-or-leave-it offer maximizes the present value of

3.4. Exogenous State Variables

There is a total of five exogenous state variables in the model: the four productivities of foreign manufacturers and local service providers and the union bargaining power, β. We assume that the pair β takes one of two values: β_H or β_L, where $\beta_H > \beta_L > 0$. In the H state, the union's bargaining power is high, and in the L state it is lower. We initiate the economy in the H state, which we take to represent the period right after the end of the war, and let it evolve according to the Markov process below.

	β_H	β_L
β_H	$1-\varepsilon$	ε
β_L	0	1

The probability of transitioning to a state where workers have less bargaining power is given by $\varepsilon \in (0,1]$. The L state is absorbing. The stochastic specification for the evolution of the state variables captures the fact that Rust Belt industry participants acknowledged the possibility of increases in a decrease in labor bargaining power, but were uncertain of its timing (Clark, 1982; Serrin, 1973).

To mirror our focus on symmetric equilibria in the domestic manufacturing sector, we assume that all foreign Rust Belt firms produce with productivity z^{*R} and foreign Rest-of-Country firms do so with productivity z^{*S}. As we show later, this specification enables us to capture all the salient features of the wage premia and trade patterns over the course of the time period in question.

3.5. Endogenous State Variables

It is useful to summarize the endogenous state variables once more, for clarity. There are two aggregate endogenous state variables: Z, which is the set of all productivities, and U, which is the unionization rate. In addition, each individual worker has status $\upsilon \in \{0,1\}$, which governs whether he is a union member or not. Each (domestic) manufacturing firm is in the idiosyncratic state z, representing its labor productivity. In a *symmetric equlibrium* this productivity takes on one of two values: z^R for manufacturing firms in the Rust Belt, and z^S for those in the Rest of the Country.

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union membership. In the empirically relevant model parameterizations, the results of the atemporal Nash bargaining and the dynamic model are quantitatively very similar. This simply reflects the fact that both models are parameterized to generate the same wage premia.

3.6. Domestic Manufacturing Firms' Problem

We now consider the problem of a domestic producer of a single intermediate manufactured good. It is useful to divide the firm's problem up into its static and dynamic components. The firm's static problem is to maximize current-period profits by choosing prices and labor inputs for domestic consumption and exports, subject to the demand curves for the firm's output and the production function. Dynamically, each firm selects its rate of productivity growth, which entails a trade-off between the contemporaneous cost of investment and the dynamic gain from higher labor productivity down the road.

We begin with the static profit maximization problem. For a firm with productivity z, the formal maximization problem is:

$$\Pi(Z,U,z;\beta) = \max_{p_m^D,\, p_m^{EX},\, l_m^D,\, l_m^{EX},\, y_m^D,\, y_m^{EX}} \left\{ p_m^D \cdot y_m^D + p_m^{EX} \cdot y_m^{EX} - \left(l_m^D + l_m^{EX} \right) \right\}, \tag{8}$$

subject to

$$\begin{aligned} y_m^D &= z_m \cdot l_m^D, \\ y_m^{EX} &= z_m \cdot l_m^{EX}, \\ y_m^D &= P_m(Z,U;\beta)^{\sigma-1} \cdot P_m^{\ell}(Z,U;\beta)^{\rho-\sigma} \cdot X_m(Z,U;\beta) p^{-\rho}, \text{ and} \\ y_m^{EX} &= P^*(Z,U;\beta)^{\sigma-1} \cdot P^{*\ell}(Z,U;\beta)^{\rho-\sigma} \cdot X^*(Z,U;\beta) \left(\tau \cdot p^{EX} \right)^{-\rho} \tau, \end{aligned}$$

where y^D denotes domestic sales and y^{EX} is the quantity produced for exports. Analogously, l^D and l^{EX} are the labor inputs and p and p^{EX} the factory-gate (f.o.b.) prices corresponding to these two destinations. The first two constraints are the production functions (for the home and export market, respectively) and the two remaining ones are the firm's demand functions for domestic sales and exports. $X_m(Z,U;\beta)$ and $P_m(Z,U;\beta)$ represent total expenditures on manufactures and the aggregate manufactures price index in the U.S., and $P_m^{\ell}(Z,U;\beta)$ is the sectoral price index for $\ell \in \{R,S\}$. Asterisks denote the corresponding price indices and aggregate expenditure abroad. Since we aren't interested in the sectoral and/or regional employment patterns abroad, we abstract from non-tradeables (services) in the rest of the world altogether and therefore drop the m (and, as we shall see later, n) subscripts. The firm's optimal factory-gate price is the standard Dixit-Stiglitz monopolist markup, regardless of destination:

$$p = \tfrac{\rho}{\rho-1} \tfrac{w}{z} = p^{EX}. \tag{9}$$

This destination independence result is standard in the literature and stems from the linearity of the production function. In essence, firms solve two distinct and independent optimization problems for domestic sales and exports.

Since domestic labor is the numeraire and the optimal price is a constant markup over marginal cost for all producers abroad, aggregate expenditures in the Rest-of-the-World are given by

$$X^*(Z,U;\beta) = \tfrac{\rho}{\rho-1} w^*(Z,U;\beta), \tag{10}$$

where the foreign wage, $w^*(Z,U;\beta)$, is a non-linear function of the aggregate state. We derive its equilibrium value in Section 3.8.

The firms' dynamic problem characterizes its innovation decision. Innovation raises the firm's future productivity and requires an investment in units of the composite manufactured good today. By this we have in mind a broad notion of investment which includes anything that increases labor productivity, such as new technologies embodied in capital equipment. We assume that increasing productivity by x percent requires $C(x,z,Z)$ units of the final good, where $C(x,z,Z)$ is convex in x and depends on the firm's current productivity, z, and the productivity of other manufacturing firms in the economy (both at home and abroad), denoted by Z. Firms purchase each unit of the final manufactured good at price $P_m(Z,U;\beta,\tau)$. The law of motion for the firm's idiosyncratic productivity is $z' = z(1+x)$.

The manufacturer's dynamic problem depends on the region (industry) to which it belongs. Let z^S be the productivity of a firm in the Rest of the Country. Its dynamic problem is given by the following Bellman equation:

$$\begin{aligned} V^S(Z,U,z^S;\beta) = \max_{x^S>0} \big\{ &\Pi^S(Z,U,z^S;\beta) - P_m(Z,U;\beta)\cdot C(x^S,z^S,Z) \\ &+ \delta E[V^S(Z',U',z^{S'};\beta')] \big\}, \end{aligned} \tag{11}$$

where $z^{S'} = z^S(1+x^S)$, and given some perceived law of motion for Z, denoted $Z' = G(Z,U;\beta)$. Thus, firms choose their productivity increase x^S to maximize static profits minus investment costs plus the discounted value of future profits, which reflects the higher productivity resulting from today's investment.

The dynamic problem for a Rust Belt firm, in contrast, is given by

$$\begin{aligned} V^R(Z,U,z^R;\beta) = \max_{x^R>0} \big\{ &(1-\beta)\Pi^R(Z,U,z^R;\beta) - P_m(Z,U;\beta)\cdot C(x^R,z^R,Z) \\ &+ \delta E[V^R(Z',U',z^{R'};\beta')] \big\}, \end{aligned} \tag{12}$$

where $z^{R'} = z^R(1+x^R)$ and the perceived law of motion for Z is, again, $Z' = G(Z,U;\beta)$. The difference between the Rust Belt firms' problem and that of other firms is that Rust Belt firms keep only a fraction $(1-\beta)$ of each period's profits. As we discuss further below, this feature captures the hold-up problem, which is modeled as an atemporal Nash bargaining protocol.

In order to stationarize the dynamic program, we deflate all idiosyncratic productivities by the average productivity of the manufacturing sector in the Rest-of-the-Country, that is, by

$$\tfrac{1}{1-\lambda}\left(\int_{\lambda}^{1}\left\{\int_{0}^{1}\left[z(i,j)^{\rho-1}\right]dj\right\}^{\frac{\sigma-1}{\rho-1}}di\right)^{\frac{1}{\sigma-1}}. \tag{13}$$

In the symmetric equilibrium underlying our quantitative exercise, this implies that all productivities are divided by z^S.

3.7. Worker's Problem

Since workers don't face an inter-temporal consumption-saving trade-off, the choice between m_t and n_t^{ℓ} is static and depends only on current prices and the workers total income. Note that an individual worker consumes manufactures and n_t^R *or* n_t^S, depending on the location of his job. The first order conditions associated with the objective function given in equation (1) together with the budget constraint of a worker employed in region $\ell \in \{R,S\}$ and sector $k \in \{m,n\}$ pin down his consumption of manufactures and local services.

To fully characterize the consumption problem we need some additional notation. Let $\mathscr{D}$ denote the per capita dividend paid by a fully diversified mutual fund and $\mathscr{R}$ the union rent of a worker employed by a Rust Belt manufacturing firm. Then, the worker's income (and hence her expenditures) are given by:

$$E_m^R = w + \mathscr{D} + \mathscr{R} \tag{14}$$

$$E_k^{\ell} = w + \mathscr{D}, \quad \text{for } (\ell,k) \in \{(R,n),(S,m),(S,n)\} \tag{15}$$

Let m_k^{ℓ} $\left(n_k^{\ell}\right)$ denote the consumption of manufactures (non-traded services) by a worker employed in region $\ell \in \{R,S\}$ and sector $k \in \{m,n\}$. Then it is straightforward to show that, for given prices

P_m (manufactures) and p_n^ℓ (services in region ℓ), the optimal quantities are characterized by:

$$m_k = \frac{E_k^\ell}{P_m + p_n^\ell \left(\frac{P_m}{p_n^\ell}\frac{1-\mu}{\mu}\right)^\theta} \tag{16}$$

$$n_k^\ell = \frac{E_k^\ell \left(\frac{P_m}{p_n^\ell}\frac{1-\mu}{\mu}\right)^\theta}{P_m + p_n^\ell \left(\frac{P_m}{p_n^\ell}\frac{1-\mu}{\mu}\right)^\theta}. \tag{17}$$

The problem of an individual worker is where to locate each period, so as to maximize expected discounted utility. Since there is no intertemporal consumption-saving decision, this is equivalent to maximizing the expected present value of income and hence expenditures. The individual state variable of a given worker is her union status, $\upsilon \in \{0,1\}$, plus the aggregate states Z and U. Also relevant for the worker's decision are the union rent and the union admission rate functions, $\mathscr{R}(Z,U;\beta,\tau)$ and $F(Z,U;\beta,\tau)$. They describe the additional payment made to a union worker relative to a non-union worker and the probability of obtaining a union card and hence the right to work a union job, respectively.

Let $W_m^R(Z,U,\upsilon;\beta,\tau)$ and $\widetilde{W}(Z,U,\upsilon;\beta,\tau)$ be the values of being employed by a manufacturing firm in the Rust Belt and any other firm, respectively. The worker's value function is:

$$W(Z,U,\upsilon;\beta) = \max\{W_m^R(Z,U,\upsilon;\beta), \widetilde{W}(Z,U,\upsilon;\beta)\}. \tag{18}$$

First, consider the value of being a manufacturing worker in the Rust Belt. For non-union workers, i.e. $\upsilon = 0$, the value is given by

$$\begin{aligned} W_m^R(Z,U,0;\beta) = {} & F(Z,U;\beta) \times \left\{ v^R\big(1 + \mathscr{R}(Z,U;\beta,\tau) + \mathscr{D}\big) + \delta(1-\zeta)E[W(Z',U',1;\beta')] \right\} \\ & + (1 - F(Z,U;\beta)) \times \left\{ v\big(1+\mathscr{D}\big) - \bar{u} + \delta(1-\zeta)E[W(Z',U',0;\beta')] \right\}, \end{aligned} \tag{19}$$

where v^R is the indirect utility function corresponding to u^R in equation (1), $v = \max\{v^R, v^S\}$, and the wage rate is normalized to unity.

In other words, a non-union worker who applies for admission to a labor union gets a union card with probability $F(Z,U;\beta)$, which entitles her to work in a unionized manufacturing firm in the Rust Belt. In this case she is paid the competitive wage (normalized to one) plus the union rent, the per capita dividend from the fully diversified mutual fund, plus the expected discounted value of union membership in the future. With probability $1 - F(Z,U;\beta)$ she doesn't receive a card, in which case she gets the competitive wage plus the dividend minus the utility cost $\bar{u}$ of "queueing" unsuccessfully for union membership, plus the expected discounted value of not being a union member next period.

For union members, i.e. $\upsilon = 1$, the value of locating in the Rust Belt is:

$$W_m^R(Z,U,1;\beta) = v^R\big(1+\mathscr{R}(Z,U;\beta)+\mathscr{D}\big)+\delta(1-\zeta)E[W(Z',U',1;\beta')], \tag{20}$$

which is the indirect utility from the competitive wage, the union rent, and the dividend today, plus the expected discounted value of being a union member in the future. Note that in all the parameterizations we consider, union members never quit a Rust Belt manufacturing job and always earn the union wage premium in equilibrium. They exit only via attrition, at the exogenous rate ζ.

Next, consider the value of employment in a non-union sector and region. In this case, a worker with union status υ has value function:

$$\widetilde{W}(Z,U,\upsilon;\beta) = v\big(1+\mathscr{D}\big)+\delta(1-\zeta)E[W(Z',U',\upsilon;\beta')], \tag{21}$$

which is the indirect utility from today's competitive wage and dividend, plus the expected discounted value of having union status υ in the future. Non-union workers outside the Rust Belt manufacturing sector are paid the competitive wage and mutual fund dividend today plus the expected discounted utility of being a non-union worker in the future. Union members outside the Rust Belt manufacturing sector get the competitive wage today plus the expected discounted utility of being a union member in the future.

The worker's problem is easy to characterize. As long as union rents are positive, union members will strictly prefer to locate in the Rust Belt. In contrast, non-union workers will be indifferent between locating in the two regions only for one particular job finding rate, $F(Z,U;\beta,\tau)$, all else equal. Following previous spatial models, such as the model of Desmet and Rossi-Hansberg (2014), we focus on an equilibrium where (non-union) workers are indifferent across locations. We also restrict attention to the symmetric recursive competitive equilibrium where firms within each region make the same decisions and have the same productivity level each period.[11]

3.8. Trade Balance and Foreign Wage

We require balanced trade each period. Put differently, expenditures on manufactures from abroad must equal foreign expenditures on manufacturing exports from the United States. Since we are

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[11] Most of our results are robust to relaxing the symmetry restriction. In particular, since the innovation decision does not depend on the firm's idiosyncratic productivity, the distribution of productivities *within* a sector and region is stationary, up to an endogenous scale parameter.

focusing on a symmetric equilibrium, we can write the balance condition as follows:

$$\lambda p^{*R}y^{*R,EX}+(1-\lambda)p^{*S}y^{*S,EX}=\lambda p_m^R y_m^{R,EX}+(1-\lambda)p_m^S y_m^{S,EX}, \tag{22}$$

where the superscript *EX* denotes exports.[12] U.S. expenditures on foreign goods are on the left hand side of the equation and foreign expenditures on U.S. goods are on the right hand side.

Recall that foreign expenditures on manufactures equal $E^*=\frac{\rho}{\rho-1}w^*$. The demand structure for manufactures at home is somewhat more complex. Firms demand final goods since it is the sole input into the innovation technology and the firms' total demand equals the aggregate cost of innovation. Workers spend a fraction of their income, denoted by E_k^ℓ for $k\in\{m,n\}$ and $\ell\in\{R,S\}$, on manufactures. Along the symmetric equilibrium path of the economy, aggregate demand for manufactures, denoted by X_m, is therefore given by:

$$\begin{aligned}X_m=P_m\Bigg\{&\left(\lambda C(x_m^R)+(1-\lambda)C(x_m^S)\right)\\&+(w+\mathscr{D})\left(\frac{l_m^R+l_n^R}{P_m+p_n^R\left(\frac{P_m}{p_n^R}\frac{1-\mu}{\mu}\right)^{\theta}}+\frac{l_m^S+l_n^S}{P_m+p_n^S\left(\frac{P_m}{p_n^S}\frac{1-\mu}{\mu}\right)^{\theta}}\right)+\mathscr{R}l_m^R\Bigg\}\end{aligned} \tag{23}$$

where

$$l_m^R=\lambda\left(l_m^{R,D}+l_m^{R,EX}\right) \tag{24}$$

$$l_m^R=(1-\lambda)\left(l_m^{S,D}+l_m^{S,EX}\right) \tag{25}$$

We can close the model by solving the trade balance equation for the foreign wage rate w^*:

$$w^*=\frac{w^{1-\rho}\frac{\rho}{\rho-1}P^*(w^*)^{\sigma-1}\left[\lambda(z_m^R)^{\rho-1}\left(P^{*R}(w^*)\right)^{\rho-\sigma}+(1-\lambda)(z_m^S)^{\rho-1}\left(P^{*S}(w^*)\right)^{\rho-\sigma}\right]}{P_m(w^*)^{\sigma-1}X_m\left[\lambda(z^{*R})^{\rho-1}\left(P_m^R(w^*)\right)^{\rho-\sigma}+(1-\lambda)(z^{*S})^{\rho-1}\left(P_m^S(w^*)\right)^{\rho-\sigma}\right]}. \tag{26}$$

3.9. Investment Cost Function

We select the functional form for the cost function such that the model has several desirable properties. In particular, the cost function is strictly convex and increasing. Moreover, the cost in terms of final goods is homogeneous of degree zero so that the model is scale invariant. This allows us to express all productivities relative to a benchmark producer, which we choose to be a Rest-of-the-Country manufacturing firm. More specifically, this is equivalent to requiring that the cost

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[12] For instance, $y^{*R,EX}$ denotes the quantity of foreign Rust Belt goods exported to the United States.

of innovation in units of the numeraire, $C(x,Z,z) \cdot P_m(Z,U;\beta,\tau)$, be homogeneous of degree zero with respect to all the productivities. The lack of scale effects has a long tradition in the growth literature (see e.g. Jones, 1995) and it guarantees that we can solve all the Bellman equations using numerical tools that are standard in stationary dynamic programming.

As we show in Appendix B, a cost function that satisfies these requirements is:

$$C(x,Z,z) = \alpha x^{\gamma} \frac{z^{\rho-1}}{\mathscr{Z}}, \tag{27}$$

where the denominator, $\mathscr{Z}$, is:

$$\mathscr{Z} = \left(\int_0^1 \left\{ \int_0^1 \left[z(i,j)^{\rho-1} + z(i,j)^{*\rho-1} \right] dj \right\}^{\frac{1-\sigma}{1-\rho}} di \right)^{\frac{2-\rho}{1-\sigma}}. \tag{28}$$

The parameters α and γ govern the scale and curvature of the cost function.[13]

4. Quantitative Analysis

We now turn to a quantitative analysis of the model to assess how much of the employment share decline from 1950-2000 can plausibly be accounted for by labor market conflict in the Rust Belt. We calibrate the differences in labor market competition between the Rust Belt and the Rest of the Country using the evidence on wage premiums we presented in Section 2. We choose a conservative value for the elasticity of substitution across sectors, drawn from the low end of values estimated in the literature. We find that the calibrated model accounts for around half of the observed drop in the Rust Belt's manufacturing employment share.

4.1. Parameterization

We choose a model period to be five years, and, accordingly, set the discount rate to $\delta = 0.96^5$. For the elasticity of substitution we set $\sigma = 2.7$, based on the work of Broda and Weinstein (2006), who estimate elasticities of substitution between a large number of goods and find median elasticities between 2.7 and 3.6, depending on the time period and degree of aggregation. We set the elasticity of substitutions between varieties to $\rho = 4$, which delivers a markup of 33 percent, consistent with those estimated by Collard-Wexler and De Loecker (2015) for the U.S. steel industry. In terms

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[13] In the symmetric equilibrium, the denominator simplifies to:

$$\mathscr{Z} = \left(\lambda \left[\left(z_m^R\right)^{\rho-1} + \left(z_m^{*R}\right)^{\rho-1} \right]^{\frac{1-\sigma}{1-\rho}} + (1-\lambda) \left[\left(z_m^S\right)^{\rho-1} + \left(z_m^{*S}\right)^{\rho-1} \right]^{\frac{1-\sigma}{1-\rho}} \right)^{\frac{2-\rho}{1-\sigma}}.$$

of initial conditions, we set $z_{S,0} = z_{R,0} = z^*_{S,0} = 1$, though we have found that our results are not sensitive to these values given our calibration strategy. For the transition matrix for β and τ, we choose a value of $\varepsilon = 1/6$, corresponding an expected 6 model periods in the initial high state, or 30 years.

Table 3: Parameters Used in Quantitative Analysis

Moment	Value
δ – discount factor (five-years)	0.82
σ – elasticity of substitution between sectors	2.70
ρ – elasticity of substitution between varieties	4.00
ε – probability of transition to more competitive state	0.17
λ – share of sectors in Rust Belt	0.53
γ – curvature term in cost function	1.80
α – linear term in cost function	7.08
χ – productivity growth rate of foreign sector	0.02
τ_H – trade costs in high-distortion state	3.50
τ_L – trade costs in low-distortion state	2.68
β_H – labor bargaining in high-distortion state	0.36
β_L – labor bargaining in low-distortion state	0.12
$z^*_{R,0}$ – initial foreign productivity level	2.30

We calibrate the remaining nine parameters to jointly match nine moments in the data. The parameters to calibrate are: (i) λ, the share of goods produced in the Rust Belt, (ii and iii) γ and α, the curvature and linear terms in the investment cost function, (iv) χ, the productivity growth rate of the foreign sector, (v and vi) τ_H and τ_L, the trade costs pre- and post-1980, (vii and viii) β_H and β_L, the labor bargaining terms pre- and post-1980, and (ix) $z^*_{R,0}$, the initial foreign Rust Belt productivity level.

The nine moments we target are: (i) the initial employment share of 51 percent in the Rust Belt, corresponding to the actual share in 1950; (ii) an average innovation investment-to-GDP ratio of 8.5 percent, which is the average ratio of investments in R&D, advertising and other intangibles to GDP in the United States (Corrado, Hulten, and Sichel, 2005; McGrattan and Prescott, 2010; Acemoglu, Akcigit, Bloom, and Kerr, 2013); (iii) a long-run output growth rate of 1.8 percent per year; (iv) a foreign output growth rate of 2 percent per year; (v and vi) an average aggregate import share of 4 percent and 9 percent in the periods pre- and post-1980; (vii and viii) the Rust Belt wage premium of 12 percent and 4 percent pre- and post-1980, as in Figure **??**; (ix) the Rust Belt's average import shares pre-1980 of 8 percent, which we proxy by the average import share

Table 4: Moments Targeted: Model vs Data

Moment	Model	Target
Initial employment percent of Rust Belt	51.30	51.30
Innovation as a percent of GDP	8.50	8.50
Long-run annual GDP growth rate (%)	1.80	1.80
Aggregate import share, 1950-1980 average	3.99	4.00
Aggregate import share, 1980-2000 average	8.98	9.00
Rust Belt wage premium, 1950-1980 average	12.00	12.00
Rust Belt wage premium, 1980-2000 average	4.00	4.00
Rust Belt import share, 1950-1980 average	7.99	8.00

in automobiles and steel.

Table 3 reports the value of each parameter used in the calibration. The model matches the desired moments quite well, and in all cases to the second decimal place. For completeness we report each moment and its model counterpart in Table 4. While all moments above jointly discipline all the parameters, it is useful to provide some intuition about which moments are most informative about each parameter. The initial employment share in the Rust Belt, (i), is most informative about λ, since λ controls the fraction of goods produced in the Rust Belt. The investment-to-output ratios and long-run growth rates, (ii) and (iii), are most informative about the scale and curvature terms in the cost function, α and γ. The aggregate import shares largely govern the trade costs, τ_H and τ_L, and the initial Rust Belt import share largely governs the initial foreign Rust Belt productivity, $z^*_{R,0}$. The Rust Belt wage premia largely govern the worker bargaining power, β_H and β_L.[14]

4.2. Quantitative Predictions

With the model calibrated to the actual 1950 employment shares, we compute the equilibrium of the model and solve for the evolution of regional employment shares, productivity growth rates, and other endogenous variables, given the expectations of the state vector described above, and imposing that that the state switches from the high distortion state to the low-distortion state in 1985. Recall we impose this shift in the state to account for the increase in trade, and to account for the decrease in labor bargaining power, as described in Section **??**.

Figure 4 plots the model's manufacturing employment share of the Rust Belt from 1950 to 2000 and the data. The first salient feature of the figure is that the model predicts a large secular de-

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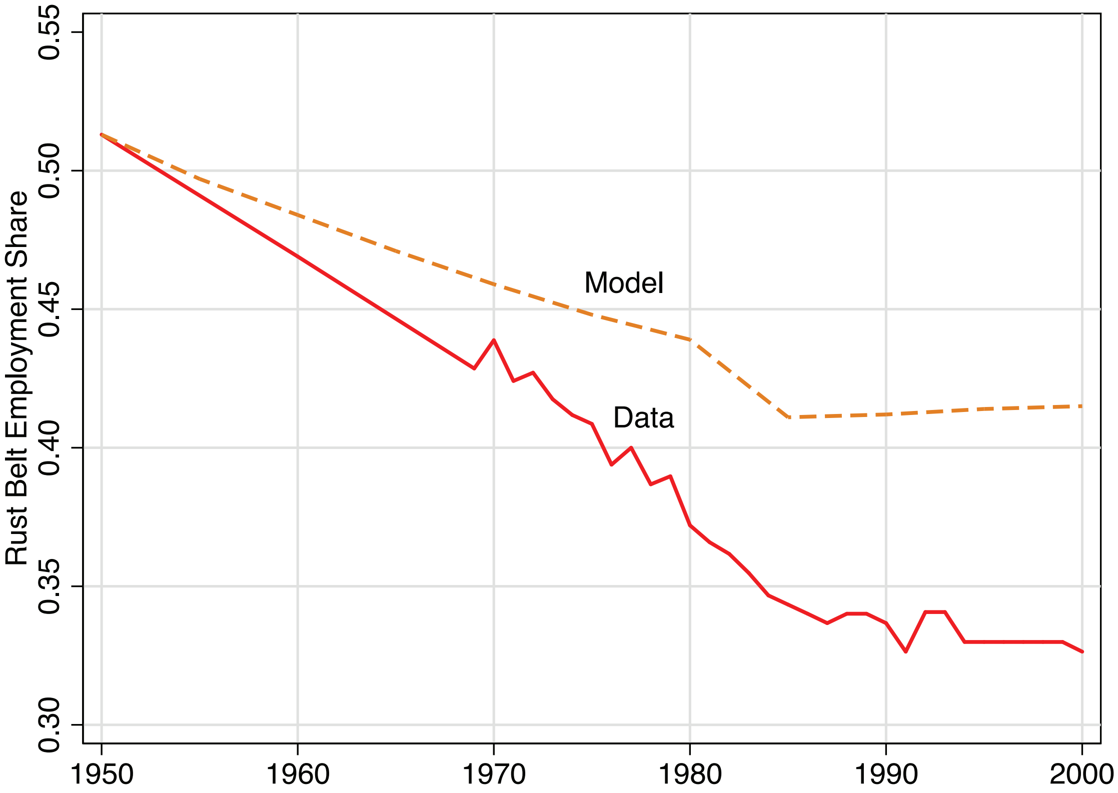
[14] In our parameterized model, the foreign productivity growth rate is higher than the asymptotic domestic average productivity growth rate. We make this assumption as a simple way to capture increased competition from abroad over the period 1950 to 2000.

Figure 4: Manufacturing Employment Share in Rust Belt: Model and Data



cline in the Rust Belt's employment share, similar to the data. This decline is simply the natural evolution of lower investment and lower productivity growth that follows from the union hold-up problem. Overall, the model predicts a drop of 9.8 percentage points, compared to 18 percentage points in the data. Thus, the model accounts for 54 percent of the overall decline in the data.

A second salient feature of Figure 4 is that the model's predicted decline is more pronounced between 1950 and 1980 than in later years, and that, again, mirrors the decline in the data. The model predicts a drop of 10.2 percentage points until 1980, compared to a 14.3 percentage point drop in the data. After 1980, the Rust Belt's employment share predicts a modest gain of 0.4 percentage points, compared to a decline of 2.5 percentage points in the data.

Why does the model predict a steeper decline before 1980 than afterwards? The reason is that the hold-up problem before 1980 depresses investment in the Rust Belt, and thus lowers productivity growth. This persistent cross-regional difference in productivity growth leads to a persistent rise in the relative price of Rust Belt goods, which in turn leads to a persistent shift in economic activity out of the Rust Belt. After 1980, when competition increases, two effects play important roles. First, the decrease in trade costs imply that the Rust Belt's employment share drops sharply, since the foreign sector has a comparative advantage in the goods that the Rust Belt produces. In the data this is visible in the manufacturing sector right after 1980; in the model, the decline is 3.1 percentage points from 1980 to 1985 alone. The second effect is that the lower union bargaining power (lower values of β) reduces the hold-up problem, which increases investment and productivity growth. This in turn arrests the decline in the Rust Belt's share of employment. In the data, the Rust Belt's share of employment is largely flat after 1985, while the model predicts an increase of 0.6 percentage points.[15]

While we do not target regional labor productivity growth rates in our calibration, the model performs reasonably well from 1950-1980 in this respect. It generates an average growth rate of 1.4 percent annually in the Rust Belt, compared to 2.0 percent in the data. The corresponding growth rates for the Rest of the Country are 1.9 percent (model) and 2.6 percent (data). Thus, the model delivers rates and regional rate differentials that track their empirical counterparts reasonably closely in this period. After 1980, the Rust Belt's productivity growth rises sharply in the data to 4.2 percent per year on average. The model also predicts a rise in productivity growth, but not as sharp as in the data. In the model, productivity growth rises to 2 percent per year.[16]

Figure 5 displays the aggregate and Rust-Belt import shares in the model and data. The green solid line is the average import share in the automobile and steel industries, which we use as a crude proxy for the Rust Belt's import share. Steel and automobiles are among the most prominent Rust Belt industries, and the only two for which we could find data on import shares going back to 1950. Given the intense focus on import protection policy for the steel and auto industries, one may suspect that these two industries faced the relatively strongest increases in industry-specific import competition (see e.g. Clark (1982) and Clark (1985)).[17] The red solid line is the aggregate import share, which we acquired from FRED. The model's calibrated import shares in the model are displayed in Figure 5 as the two dashed lines. While stylized, our model does deliver some of the key features of the import data, namely the sharp increase around 1980, the greater increase in the Rust Belt's import share, and (some of) the steady secular increases in import shares throughout the period.[18]

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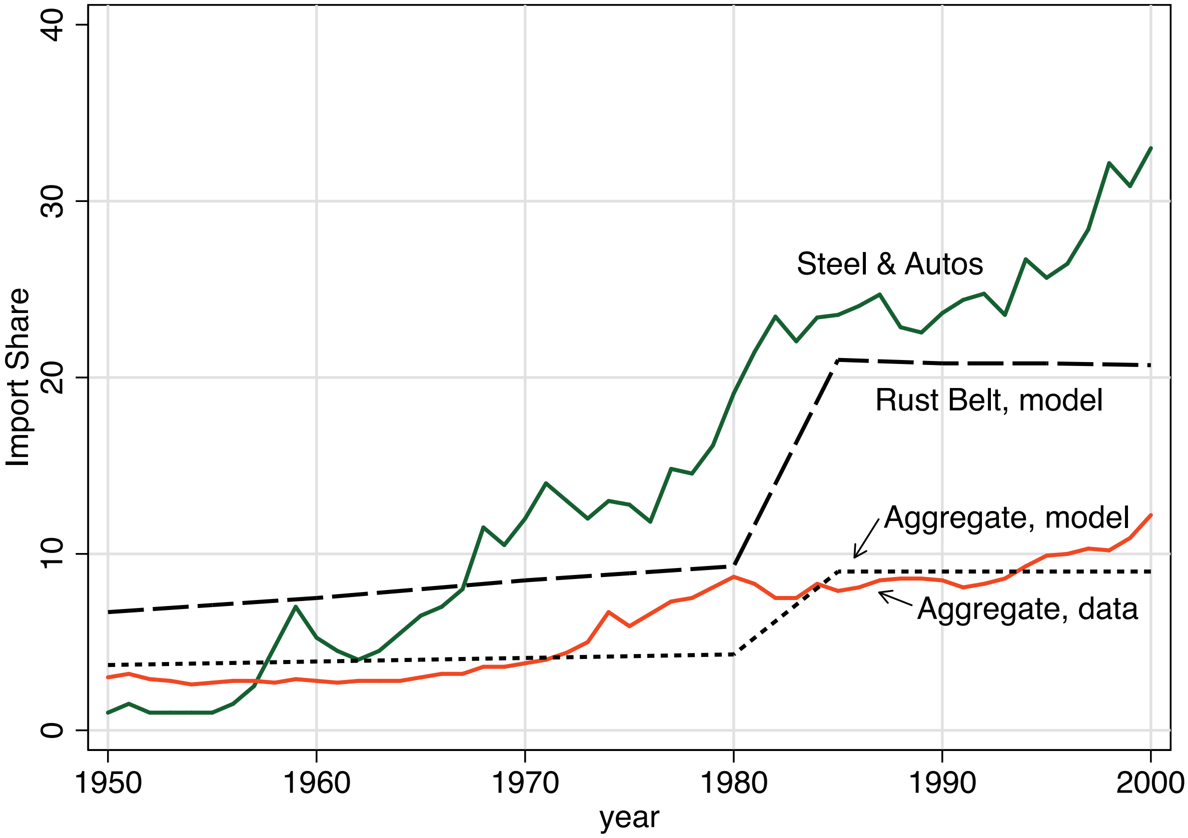
[15] Another force that may have served to stabilize the Rust Belt's share of manufacturing is that since the 1990s, imports have mainly affected areas outside the Rust Belt. See (Autor, Dorn, and Hanson, 2013b).

[16] We plot the model's productivity growth rates by region in Appendix Figure A.1. Some of the additional productivity increases after 1980 may have come from improved work practices and reduction in union work rules, neither of which we model explicitly. See Schmitz (2005) and Dunne, Klimek, and Schmitz (2010) for evidence of reductions in union work rules raised productivity in the iron ore and cement industries in the 1980s.

[17] We computed the steel import shares using data on imports and output from the American Steel Institute and from Wards Auto, respectively.

[18] For a much later time period, Autor, Dorn, and Hanson (2013a) and Autor, Dorn, Hanson, and Song (2014) document that workers in U.S. industries that are more exposed to imports from China since 1990 have experienced substantial negative wage growth and labor market outcomes. However, since imports from China were only 2 percent in 1990 and negligible before that, imports from China are quite unlikely to have played an important role in the Rust

Figure 5: Import Shares: Model and Data



The model's predictions for import shares in the Rust Belt after 1980 are not targeted directly, but, as in the data, are substantially higher than in the aggregate. In the data, Rust Belt import shares (proxied by automobiles and steel) rise sharply around 1980 from just over 10 percent to around 25 percent. In the model, import shares are around 10 percent in 1980 and rise to 21.3 percent on average afterwards. Part of the reason the model delivers the much higher import share in the Rust Belt than in the aggregate is the exogenous comparative advantage of the foreign sector in Rust Belt goods chosen to match the pre-1980 import shares. However, much of the model's success comes from the endogenous comparative advantage of the foreign sector brought about by the Rust Belt's lack of investment in the decades prior to the fall in trade costs.

Several other features of the Rust Belt's economy in the model are consistent with the data. The

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Belt's decline from 1950 to 1990. Furthermore, most of the affected regions were located outside the Rust Belt (see Autor, Dorn, and Hanson, 2013b, Figure 1B). For the earlier period of 1977 to 1987, Revenga (1992) estimates a negative impact of import penetration on U.S. manufacturing, which is consistent with our model's predicted decline in the Rust Belt's share of manufacturing employment in the early 1980s, though again, this is after the bulk of the Rust Belt's decline had already occurred. Most of these import increases of the 1980s were from advanced economies like Japan.

regional investment-to-GDP ratios, which are not targeted directly, are lower in the Rust Belt than in the rest of the economy, particularly in the period before 1980 when competitive pressure was at its lowest. In the model, the investment-to-value added ratio averages 5.5 percent in the Rust Belt, compared to 10.3 percent in the rest of the country. This sizable difference in investment rates is due to the lower investment rate of the Rust Belt and the curvature of the investment cost function. The lower investment rate of the Rust Belt is broadly consistent with the consensus that Rust Belt industries lagged behind the rest of the country, as described in Section **??**.[19]

4.3. Decomposition of Rust Belt's Decline

The quantitative results above provide two reasons for the Rust Belt's decline. The timing and nature of these shocks provide different mechanisms that together explain around half of the Rust Belt's decreasing employment share from 1950 to 2000. In this section, we decompose the model's quantitative predictions into the hold-up channel and the import-competition channel.

We consider two alternative counterfactual scenarios. In the first, we compute the model's predictions assuming that trade costs stay at their high initial level of τ_H from 1950 to 2000. In this "no fall in trade costs" scenario, the worker bargaining power is β_H until 1980, then falls to β_L, and all else is as in the benchmark analysis. In the second scenario, we assume away the union hold-up that is at the heart of our theory. In particular, we assume $\beta = 0$ for the period 1950 to 2000, but keep all other parameters as in the benchmark, and in particular keep the fall in trade costs in 1980. We call this the "no union hold up" counterfactual.

Figure 6 plots the model's predicted employment shares in the Rust Belt under the two counterfactuals. In the "no union hold up" counterfactual (short dashed line), the Rust Belt has a slight decline of 0.9 percentage points from 1950 to 1980, which is quite inconsistent with the large decline of 14.3 percentage points present in the data. This counterfactual completely misses the large pre-1980 Rust Belt decline because the large increase in trade does not occur until after 1980. Between 1980 and 1985, the fall in trade costs generates a 1.7- percentage point decline, which is similar to the drop in the data, and for the 1985-2000 period the model predicts a slight decline of 0.5 percentage points, comparable to the data.

In the "no fall in trade costs" counterfactual, the model predicts a substantial secular decline of 7.0

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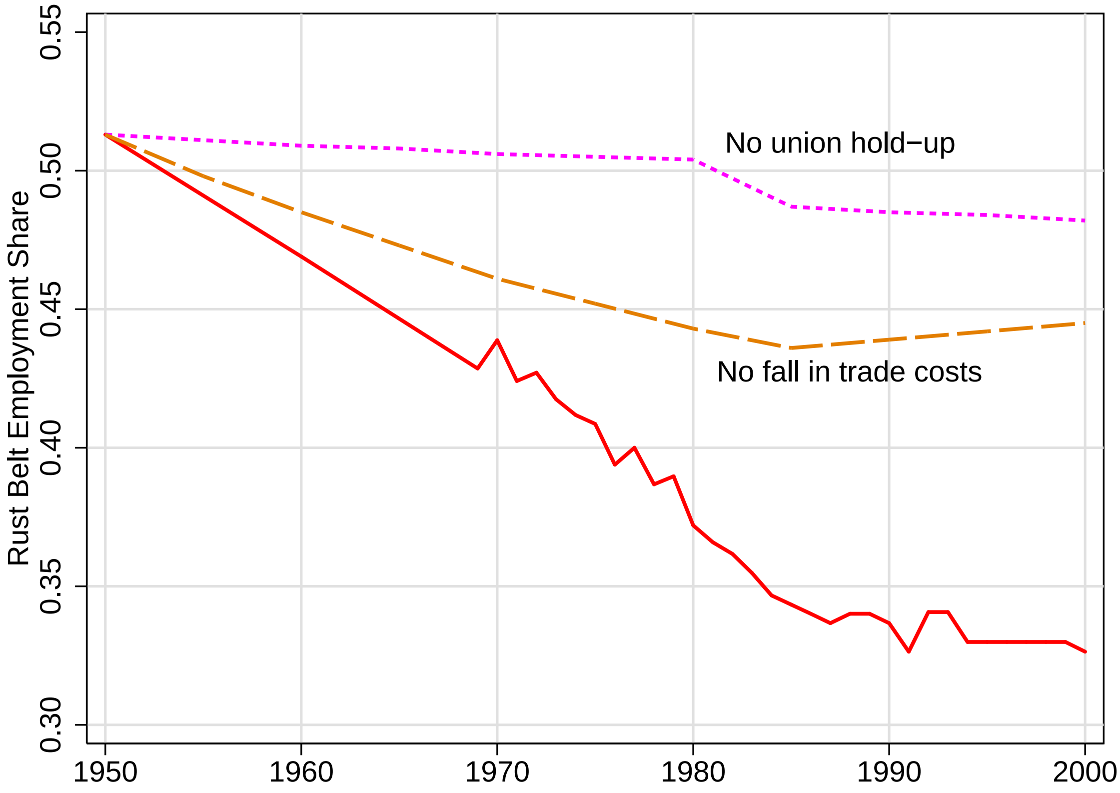
[19] For the U.S. steel industry before 1980, the majority of which was in the Rust Belt, there is a strong consensus that adoption rates of the most important technologies lagged far behind where they could have been. The two most important new technologies of the decades following the end of WWII were the basic oxygen furnace (BOF) and the continuous casting method. Even though U.S. steel producers had ample opportunity to adopt these technologies, they nonetheless were laggards in adopting them (Adams and Brock, 1995; Adams and Dirlam, 1966; Lynn, 1981; Oster, 1982; Tiffany, 1988; Warren, 2001). Similar evidence can be found for the rubber industry (see e.g. Rajan, Volpin, and Zingales (2000) and French (1991)) and for the automobile industry (see e.g. Adams and Brock (1995), Ingrassia (2011) and Vlasic (2011)).

Figure 6: Decomposing the Rust Belt's Decline



percentage points through 1980, compared to 7.4 percentage points in the benchmark calibration, and to 14.3 percentage points in the data. After 1980, this counterfactual predicts a modest increase of 0.6 percentage points in the Rust Belt's share, as it catches up (somewhat) to the rest of the country. Thus, this "no fall in trade costs" counterfactual, with only the union holdup problem, does a much better job explaining the bulk of the Rust Belt's decline.

4.4. Sensitivity Analysis

We next present several sensitivity analyses. We begin by looking at how the model's predicted employment share decline of the Rust Belt varies with different targets for the elasticity of substitution. We note that our benchmark analysis takes quite a conservative choice for σ, which is the lowest median elasticity reported by Broda and Weinstein (2006). We consider two alternative values of σ: a lower value of 2, similar to the estimated value of 1.7 by Acemoglu, Akcigit, Bloom, and Kerr (2013), and a higher value of 3, closer to the middle of the range of estimates by Broda and Weinstein (2006). Each time we re-calibrate the other parameters to match the moments laid out in the previous section. We find that when the elasticity is set to 2, the Rust Belt's employment share drops by 8.7 percentage points, compared to 9.8 in the benchmark calibration. With a higher elasticity of 3, the Rust Belt loses 11.6 percentage points. The intuition for why a larger σ implies a larger decline is that a higher elasticity, for a given differential in productivity growth, leads households to substitute away from Rust Belt goods more aggressively. We conclude that within a plausible range of σ, the model accounts for between 48 percent to 64 percent of the Rust Belt's decline, similar to our benchmark value of around one half.

The second sensitivity analysis is over the parameter ρ, which governs the inner elasticity of substitution between varieties. When we choose a lower value of 3.5, rather than the benchmark value of 4, we get a decline of 9.5 percent. A higher value of 4.5 gives a decline of 9.4 percent, both similar to the benchmark decline. The intuition is that a higher ρ leads to a faster decline for the period pre 1980, as consumers substitute away from Rust Belt goods faster, but then a faster catch-up after 1980, since ρ affects the curvature in the cost function. These two forces largely offset each other so that alternative values of ρ around the benchmark make little overall difference on model's overall predicted decline.

Table 5: Sensitivity Analysis

Alternative Specification	Rust Belt Employment-Share Decline
Lower outer elasticity, $\sigma = 2.0$	8.7
Benchmark, $\sigma = 2.7$	9.8
Higher outer elasticity, $\sigma = 3.0$	11.6
Lower inner elasticity, $\rho = 3.5$	9.5
Higher inner elasticity, $\rho = 4.5$	9.4
Investment/GDP of 8 percent	9.6
Investment/GDP of 9 percent	10.3

Note: Rust Belt Employment-Share Decline is the percentage point decline in the share of manufacturing employment in the Rust Belt from 1950 to 2000.

Finally, we consider sensitivity to γ, which controls the curvature of the investment cost function, and which is the major factor impacting the share of output devoted to investment. We consider two alternative parameterizations that target investment shares of 8 percent and 9 percent, respectively, rather than the 8.5 percent target from the benchmark experiment. In these parameterizations, we maintain the 1.8 percent steady-state growth target – which requires a change in α – and fix β, λ, and σ at their baseline values. The Rust Belt's employment share falls 9.6 percentage points when investment share is 8 percent, compared to the 9.8 percentage points in the benchmark. When we instead target a 9 percent investment-to-output ratio, the Rust Belt loses 10.3 percentage points. The higher investment rate leads to a sharper decline of the Rust Belt since holding up innovation now leads to lower relative productivity growth.

5. Supporting Evidence

In this section, we examine whether our theory's predicted link between labor conflict and employment growth is borne out in disaggregated evidence at the industry-region level. In particular, we ask whether industry-state pairs with more labor conflict had lower rates of employment growth from 1950 to 2000, after including industry fixed effects and state controls such as initial industry concentration and climate variables. We consider three measures of labor market conflict in turn: major post-war work stoppages, post-war unionization rates, and strikes from 1927 to 1934, which long pre-date the period of employment growth in question. We find that all three measures of conflict are significantly negatively associated with employment growth.

5.1. Work Stoppages from 1958 to 1977

We begin by returning to the data on major work stoppages described in Section 2, which are perhaps the most direct measure of labor conflict available to us. Here, we draw on micro evidence covering all work stoppages from 1958 to 1977 that were recorded by the BLS (U.S. Bureau of Labor Statistics, 1992). We aggregate the data to the state-industry level, so that observations represent e.g. motor vehicles in Michigan or metal mining in Alabama. We then merge the work-stoppage data with census data from IPUMS, state-level temperature and climate statistics, and other variables. The complete description of our data is available in Appendix A.

The outcome of interest is the employment growth rate, measured as the log increase in state-industry employment from 1950 to 2000. Table 6 presents a set of four regressions that explore the correlates of state-industry employment growth rates. Column (1) regresses state-industry employment growth on the number of major work stoppages per year, the percent of workers that are college educated, and a set of industry fixed effects. The estimated coefficient on major work stoppages turns out to be -0.41, meaning that an additional major work stoppages per year is associated with approximately 50 percent (41 log points) lower employment growth, all else equal. The coefficient is statistically significant at the one-percent level, and economically significant as well: one more work stoppage per year is like moving from two standard deviations below the mean to two standard deviations above. Thus, the interpretation is that moving from near the bottom of the work-stoppage distribution to near the top is associated with 50 percent lower employment growth compared to the same industry in other states. The coefficient on the percent college graduate is positive, but statistically insignificant.

Column (2) adds in three additional state controls to the regression. The first control is the state population level in 1950, which may be relevant since less populous states had relatively lower land prices, and may have grown faster as a result. The second control is the share of employment

Table 6: Major Work Stoppages and Employment Growth

Independent Vars	(1)	(2)	(3)	(4)
	Dep. Var: Log Employment Growth 1950-2000			
Major Work Stoppages /Year	-0.41***	-0.30***	-0.29***	-0.27***
	(0.071)	(0.063)	(0.058)	(0.056)
Percent College Grad, 1950	0.081	0.076	0.031	-0.0012
	(0.094)	(0.094)	(0.084)	(0.074)
Log State Population, 1950		-0.045***	-0.093***	
		(0.014)	(0.015)	
State Mfg Employent Share, 1950		-1.90***	-1.02***	
		(0.13)	(0.15)	
State Empl. Herfindahl Index, 1950		-2.10***	-1.28***	
		(0.38)	(0.36)	
State Average Temperature			0.013***	
			(0.0026)	
State Std. Dev. Temperature			-0.064***	
			(0.0069)	
State Average Precipitation			-0.014***	
			(0.0013)	
Constant	-1.51***	-0.87***	-0.23	-1.40***
	(0.095)	(0.10)	(0.25)	(0.13)
Observations	5,128	5,128	5,049	5,128
R^2	0.592	0.617	0.683	0.735
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 work stoppages affecting 1,000 or more workers per year over the period 1958 to 1977, 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

in manufacturing. As Desmet and Rossi-Hansberg (2009) show, manufacturing industries with the highest employment levels in the 1970s had the slowest employment growth over the following decades; hence, controlling for the initial manufacturing share makes sense in this setting. The third control is a Herfindahl index of employment within each state, which measures how concentrated the state's employment was in particular industries in 1950. The decline of transportation costs since 1950 may have reduced the agglomeration advantages of one firm locating near another firm in the same industry, which may have lead to lower employment growth for states with initially more concentrated employment.

The estimates in column (2) show that indeed, higher population levels, higher manufacturing shares and higher concentrations of employment by industry are all associated with lower employment growth since 1950. For all three variables, the coefficients are statistically significant at the five-percent level or lower, and collectively these variables reduce the magnitude of the estimated coefficient on work stoppages. Still, the estimated coefficient on work stoppages remains economically large, at -0.30, and statistically significant at the one percent level.

Column (3) adds controls for three state climate characteristics: the average temperature, the within-year standard deviation of monthly temperature, and the average precipitation level. State climate differences have been put forth as determinants of cross-state employment and population dynamics by Rappaport (2007), among others, and the advent of air-conditioning clearly played an important role in the population increases in Sun Belt states like Arizona and Florida. We compute all three variables using data from the five years before and after 1950, though the variables are highly correlated across years for each state. As one might expect, industries in states that had lower temperatures, more variable temperatures within the year or more rainfall on average had lower employment growth from 1950 to 2000, all else equal. With these climate variables in the regression, the R^2 rises to 0.683, up from 0.617 in Column (2) and 0.592 in Column (1). Thus, the temperature controls substantially increase the explanatory power of the regression. The coefficient on work stoppages remains quite similar in magnitude, however, at -0.29, and remains statistically significant at the one-percent level.

Column (4) adds a state fixed effect (but removes the other state variables) to capture any other state conditions potentially relevant for employment growth outcomes. Adding state fixed effects raises the R^2 further to 0.735, meaning that other state factors explain a substantial portion of the variance in employment growth. Still, the coefficient on work stoppages remains large in magnitude, at -0.27, and statistically significant. Thus, employment growth since 1950 is strongly related to work stoppages at the industry-state level, even after controlling for industry fixed effects and state fixed effects. In Appendix A, Table A.3, we explore sensitivity to various modeling assumptions and sample selection choices made in the regressions above. We find that the coefficient on work stoppages is still statistically and economically significant when using alternative definitions of major work stoppages (such as 2,000 or more, or 500 or more workers), when using any positive number of workers, or when using the fraction of all workers involved in strikes. We also find that the coefficient is negative and significant when restricting the analysis only to manufacturing industries, in which labor conflict is most prevalent, or when considering employment growth from 1950-1980, a period that corresponds more closely to the work stoppage data.

5.2. Unionization Rates, 1973 to 1980

We next turn to an alternative measure of labor market conflict: the unionization rate. As described in Section 2, unionization has historically been related to labor conflict, though as Table 1 showed, unionization rates are not linked one-for-one with work stoppages. Another advantage of unionization as a proxy for conflict, relative to work stoppages, is that there may be conflict and hold up even without work stoppages. 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.

Table 7 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 6. 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 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.

5.3. Strikes from 1927 to 1934

While the results of Tables 6 and 7 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 predated the postwar employment outcomes that are the dependent variables in Tables 6 and 7. 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

Table 7: Unionization Rates and Employment Growth

Independent Vars	(1)	(2)	(3)	(4)
	Dep. Var: Log Employment Growth 1950-2000			
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. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

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.[20]

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[20] 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. See Appendix A for more detail on these data.

Table 8: Strikes/Year 1927-1934 and Postwar Employment Growth

	(1)	(2)	(3)	(4)
Independent Vars	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

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

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

Table 8 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 Tables 6 and 7. 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 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 post-war work stoppages variable? The standard deviation of strikes from 1927 to 1934 is 32, so moving from one standard deviations below the mean to one standard deviations 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 6 and 7. Overall, the results of Table 8 provide evidence against a reverse-causality story running from industry decline to conflict. Instead, the results of suggests that the the causality runs from strikes to employment growth, consistent with the thesis of this paper.

6. Conclusion

This study builds a theory of the Rust Belt's decline since the end of World War II. We focus our theory on four main observations: (1) the Rust Belt's significant wage premium from 1950 to 1980, (2) the low average productivity growth in Rust Belt industries up to 1980, (3) the conflicted relations between Rust Belt firms and workers, featuring a constant threat of strikes, until 1980, and (4) the shift in all of these patterns after 1980, when the wage premium fell, productivity growth increased, and the number of strikes dropped dramatically. In short, our theory is that the Rust Belt declined largely because of labor market conflict, which resulted in a hold-up problem that reduced investment in the Rust Belt's main industries. This lack of investment led to movement of manufacturing employment out of the Rust Belt and into the rest of the country. After 1980, labor conflict declined, leading to higher rates of investment and productivity growth and the region's stabilization.

The substantial loss of Rust Belt employment raises the important question of why management and labor were not able to share rents more efficiently. Our model indicates that the Rust Belt's employment losses were implicitly self-inflicted, as these losses would have been much smaller had unions and firms been able to eliminate the chronic conflict and strike threats that characterized their relations. Importantly, both Rust Belt management in autos and steel, and leaders of auto and steel unions acknowledge that lack of cooperation and mistrust were central in the failure of the Rust Belt (see Strohmeyer (1986), Hoerr (1988) and Walsh (2010).) Specifically, former UAW President Robert King stated in 2010 (see Walsh (2010)) that: “The 20th-century UAW fell into a pattern with our employers where we saw each other as adversaries rather than partners. Mistrust became embedded in our relations...this hindered the full use of the talents of our members and promoted a litigious and time-consuming grievance culture.” Future research should further analyze how labor relations and bargaining between workers and firms affect industry innovation, productivity growth, and competitiveness.

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Appendix (for Online Publication)

A. Data Appendix

Regional Cost-of-Living Differences, 1966

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.

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.1 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.

Table A.1: 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.

Average Wage Losses After Displacement

In order to compute average wage losses after displacement, we draw on the CPS Displaced Worker supplement from 1986. This is the earliest available CPS survey with supplemental questions for workers suffering a displacement from an employer. The main information of interest is whether the respondent was displaced from a job in the previous five years, and if so, what their wages were in the new job compared to the previous job. In our analysis, we restrict attention to hourly wage workers between 25 and 65 that lost their jobs due to a worker's plant or company closing or moving away. To measure wage loss from displacement, we compute the average weekly earnings at each worker's pre-displacement job divided by the average weekly earnings in their new job. We drop any workers with missing earnings or employment data, and the top and bottom one percent of wage changes. We then compare average wage loss for workers in the Rust Belt to workers in the rest of the country.

Table A.2: Percent Weekly Earnings Loss Among Displaced Workers, 1981-1986

	Region		
	Rust Belt	Rest of Country	Difference (*p*-value)
Mean	51.1	35.5	15.6 (0.07)
Median	20.5	11.5	9.0 (0.13)

Note: The table reports the mean and median percent weekly earnings loss for workers that were displaced from a job between 1981 and 1986, by region of the United States. The data comes from the Displaced Worker's Supplement to the 1986 CPS. Displacement means that the worker's plant or company shut down or moved. Wage loss is measured as the percent difference between the pre-displacement weekly earnings and the weekly earnings in 1986. The sample is restricted to workers that were full-time wage workers between age 25 and 65 at the time of their displacement, and who worked for a wage in 1986. The p-values are for a $t-$test of the difference in mean wage loss by region and a Wilcoxon rank-sum test of the equality of the distributions of wage loss by region.

Table A.2 presents our findings. When comparing mean wage loss, workers from both regions average very large wage losses, though these losses are higher in the Rust Belt. Displaced workers from the Rust Belt lose an average of 51.1 of their prior wages, while workers from the rest of the country lose 35.5 percent. The difference, of 15.6 percentage points, is statistically significant at seven percent level. Given how large the mean wage losses are, we compute also the median wage loss. Rust Belt workers lose a median of 20.5 percent of their prior wages, while workers from the rest of the country lose 11.5 percent. This difference, of 9 percent, has a p-value of 0.13.

One limitation of this analysis is that the sample size is fairly small. There are 84 displaced workers in our sample from the Rust Belt, and 229 from the rest of the country. The reason for the small sample size is that only a fraction of the CPS was asked the Displaced Worker questions, and of those, only a fraction were actually displaced. A second limitation is that the period in question is from 1981 to 1985, and this was largely after the large wage premiums we document in the Rust Belt had fallen.

Alternative Regression Specifications

In this subsection, we explore alternative robustness specifications. Table A.3 presents the estimated coefficients on work stoppages from regressions like those in Table 6, with each row representing the results of one alternate specification. As in Table 6, the dependent variable is log employment changes between 1950 and 2000 and the observations are state-industries. The other independent variables are exactly as in Table 6.

Table A.3: Robustness of State-Industry Regressions

	(1)	(2)	(3)	(4)
Alternative Regression	Regression Specification			
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)
Dep. Var: Log Employment Growth 1950-1980	-0.20***	-0.12***	-0.11***	-0.089***
	(0.041)	(0.036)	(0.032)	(0.031)
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 (except the second to last, which is log employment growth from 1950 to 1980. All else as in Table 6 except where indicated. Coefficients on all other independent variables are omitted for brevity. Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

As a frame of reference, the first row of Table A.3 reproduces the benchmark results of Table 6, 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 regression still show a substantial importance of work stoppages on employment growth at the industry state level. The reason is that, as the threshold for number of workers affected falls, the number of work stoppages affecting those fewer number of workers rises. 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 artifacts 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 cases. Thus, our results are robust to this more continuous measure of work stoppages.

The final two rows of Table A.3 stick with the benchmark independent variable of work stoppages affecting more than 1,000 workers, but change the dependent variable and sample selection. In particular, the first of these replaces log employment growth from 1950 to 2000 with log employment growth from 1950 to 1980. This time period is closer to the time period in which we observe work stoppages. Work stoppages again shows up as having a negative and significant relationship to employment growth, though with a smaller magnitude relative to the benchmark. The final row of the table is the same regression as the benchmark but restricts the sample to only manufacturing industries. The estimated coefficient on work stoppages is somewhat smaller than in the benchmark specification, but still with large economic and statistical significance. We conclude that an earlier timeframe for employment growth and restriction to just manufacturing still leave our conclusions from Section 5 intact.

B. Derivation of Cost Function

The optimality condition associated with the Bellman equation of on individual producer in sector $\ell \in \{r,s\}$ is:

$$\frac{\partial C(x,Z,z)}{\partial x}\frac{P}{z} = \delta\Big\{(1-\beta)\frac{\partial \pi_\ell(Z',z')}{\partial z'} + \frac{\partial C(x',Z',z')}{\partial x'}\frac{z''}{(z')^2}P' + \frac{\partial C(x',Z',z')}{\partial z'}P'\Big\}. \tag{29}$$

Next, we need to show that the optimal policy x is homogeneous of degree 0 with respect to *all* productivities. A sufficient condition is to show that both sides of the optimality condition are homogeneous of the *same* degree with respect to the productivities since proportional changes in the productivities cancel out in that case. Since

$$C(x,Z,z) = \alpha x^{\gamma}\frac{z^{\rho-1}}{D(Z)}$$

and

$$D(Z) = \left(\lambda\left[Z_R^{\rho-1} + Z_R^{*\rho-1}\right]^{\frac{1-\sigma}{1-\rho}} + (1-\lambda)\left[Z_S^{\rho-1} + Z_S^{*\rho-1}\right]^{\frac{1-\sigma}{1-\rho}}\right)^{\frac{2-\rho}{1-\sigma}} \tag{30}$$

in any symmetric equilibrium, we can show that the derivative of the cost function with respect to the policy x is homogeneous of degree 1. Moreover, the derivative with respect to the state z is homogenous of degree 0.

Finally, the profit function of a producer in sector ℓ is:

$$\pi_\ell(Z,z) = \rho^{1-\rho}(\rho-1)^{\rho-2}z^{\rho-1}\left(P_\ell^{\rho-\sigma}P^{\sigma-1} + \tau^{1-\rho}w^{*}P_\ell^{*\rho-\sigma}P^{*\sigma-1}\right)$$

Clearly then, the derivative of $\pi_\ell(Z,z)$ with respect to z is homogeneous of degree -1.

Inspection of the price indices in section 3.6 reveals that the aggregate price index is homogeneous of degree -1 with respect to all productivities. Clearly then, both sides of the optimality condition are homogeneous of degree -1. As a result, the optimal innovation rate x is scale independent and hence homogeneous of degree 0 with respect to the productivities. Since only relative productivities matter, we normalize the productivity of a Rest of the Country producer to unity ($Z_s = 1$) each period.

The denominator of the cost function in equation (30) is one of many with the required degree of homogeneity guaranteeing that the policy x is homogeneous of degree zero with respect to all productivities. However, this particular functional form for the denominator has an additional property that we believe is useful and noteworthy in its own right. In the special case of the economy with no union hold-up ($\beta = 0$), free trade ($\tau = 1$), and no comparative advantage $\big(\frac{Z_r^*}{Z_r} =$

$\frac{Z_s^*}{Z_s} = \mu\big)$, the policy x does *not* depend on the aggregate endogenous state Z and an individual firm will grow at a constant rate regardless of its own productivity z. Put differently, the economy is on a balanced growth path.

Since the price indices are equalized across countries whenever $\tau = 1$ and countries are only differentiated by the absolute advantage (parameterized by μ), the trade balance condition (22) can be simplified to:

$$w^* = \mu^{\frac{\rho-1}{\rho}} \tag{31}$$

After substituting the expression for the foreign wage into the optimality condition (29) and exploiting the fact that $P = P^*$ and $P_\ell = P_\ell^*$ for $\ell \in \{r, s\}$, the endogenous state variables (i.e. the idiosyncratic and aggregate productivities) drop out and the optimal innovation rate is given by equation (**??**), which is only a function of the parameters and the extent of foreign's *absolute* advantage μ.

C. Appendix Tables and Figures

Table A.4: Relative Wages of Rust Belt Workers

	Relative Wages	
	1950	2000
Manufacturing workers	1.13	1.02
All workers	1.17	1.01
Full-time workers	1.17	1.04
All Workers + more detailed race controls	1.16	1.03
All Workers + more detailed race & schooling controls	1.14	1.00

Note: Relative Wages are defined as one plus the coefficient in a Mincer-type log-wage regression of a dummy variable taking the value of 1 for workers living in the Rust Belt, and 0 otherwise, interacted with years 1950 and 2000. The controls in the regression are educational attainment dummies, a quartic polynomial in potential experience, and dummies for full-time status, immigrant status, nonwhite status, sex, year, and year X Rust Belt interaction terms.

MODEL APPENDIX

In a symmetric equilibrium, the price indices are the usual CES aggregates over the prices of individual goods and sectors. More formally, for $\ell \in \{R,S\}$,

$$
\begin{aligned}
P_m^{\ell}(Z,U;\beta) &= \left((p_m^{\ell})^{1-\rho} + (\tau p^{*\ell})^{1-\rho}\right)^{\frac{1}{1-\rho}}, \\
P^{*\ell}(Z,U;\beta) &= \left((\tau p_m^{\ell})^{1-\rho} + (p^{*\ell})^{1-\rho}\right)^{\frac{1}{1-\rho}}, \\
P_m(Z,U;\beta) &= \left(\lambda (P_m^{R})^{1-\sigma} + (1-\lambda)(P_m^{S})^{1-\sigma}\right)^{\frac{1}{1-\sigma}}, \\
P^{*}(Z,U;\beta) &= \left(\lambda (P^{*R})^{1-\sigma} + (1-\lambda)(P^{*S})^{1-\sigma}\right)^{\frac{1}{1-\sigma}},
\end{aligned}
$$

where p_m^{ℓ} is given by (9) and the foreign price is $p^{*\ell} = \frac{\rho}{\rho-1}\frac{w^*}{z^*}$.

Figure A.1: Productivity Growth Rate in Model

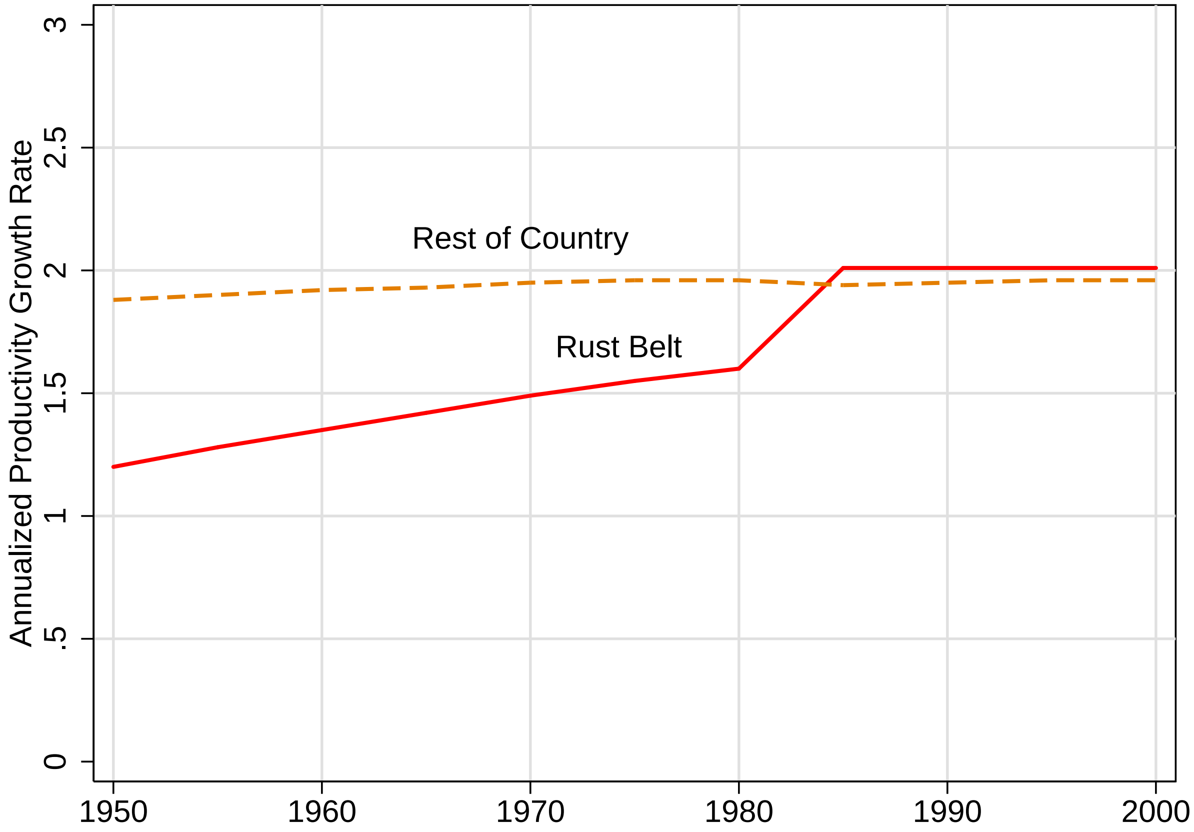

Table A.5: Labor Productivity Growth in Rust Belt Industries, Expanded Definition

	Annualized Growth Rate, %		
	1958-1985	1986-1997	1958-1997
Blast furnaces, steelworks, mills	0.9	7.6	2.8
Construction and material handling machines	0.9	2.1	1.3
Engines and turbines	2.3	2.8	2.5
Farm machinery and equipment	1.7	2.3	1.9
Iron and steel foundries	1.5	2.3	1.7
Leather products, except footwear	2.3	1.4	2.0
Leather tanning and finishing	0.7	4.5	1.8
Machinery, except electrical, n.e.c	1.0	1.5	1.2
Metal forgings and stampings	1.5	2.8	1.9
Metalworking machinery	0.9	3.5	1.6
Misc. fabricated metal products	1.1	1.7	1.3
Misc. paper and pulp products	2.6	1.9	2.4
Misc. plastics products	3.2	2.8	3.1
Motor vehicles and motor vehicle equipment	2.5	3.8	2.9
Office and accounting machines	4.8	−1.3	3.1
Other primary metal industries	−1.9	7.5	0.8
Other rubber products, plastics, footwear & belting	2.7	2.0	2.5
Paints, varnishes, and related products	3.2	2.2	2.9
Photographic equipment and supplies	4.8	5.1	4.9
Pottery and related products	0.7	−1.0	0.2
Railroad locomotives and equipment	1.6	3.0	2.0
Screw machine products	1.3	1.1	1.2
Sugar and confectionary products	3.4	3.1	3.3
Rust Belt, Expanded Definition weighted average	2.1	2.9	2.3
Manufacturing weighted average	2.6	3.2	2.8

Note: Rust Belt Industries, Expanded Definition are defined as industries whose employment shares in the Rust Belt region are more than *one-half* standard deviation above than the industry mean. 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 under the expanded definition. Manufacturing weighted average is the employment-weighted average growth over all manufacturing industries. Source: Author's calculations using NBER CES productivity database, U.S. census data from IPUMS, and the BLS.