The Decline of the U.S. Rust Belt: A Macroeconomic Analysis

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Abstract

No region of the United States fared worse over the post-war period than the "Rust Belt," the heavy manufacturing zone bordering the Great Lakes. We argue that a lack of competition in labor and output markets in the Rust Belt were responsible for much of the region's decline. We formalize this theory in a dynamic general-equilibrium model in which productivity growth and regional employment shares are determined by the extent of competition. When plausibly calibrated, the model explains roughly half the decline in the Rust Belt's manufacturing employment share. Industry evidence support the model's predictions that investment and productivity growth rates were relatively low in the Rust Belt.

Keywords: Rust Belt, competition, productivity, unionization, monopoly

JEL codes: E24, E65, J3, J5, L16, R13

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1. Introduction

No region of the United States fared worse over the post-war period than the area known as the "Rust Belt." While there is no official definition of the Rust Belt, it has come to mean the heavy manufacturing zone bordering the Great Lakes, and including such cities as Detroit and Pittsburgh. By any number of metrics, the Rust Belt's share of aggregate economic activity declined dramatically since the end of World War II.

We argue that the Rust Belt declined in large part due to a lack of competition in labor and output markets in its most prominent industries, such as steel, automobile and rubber manufacturing. The lack of competition in labor markets was closely linked to the behavior of powerful labor unions that dominated the majority of the Rust Belt's manufacturing industries. In output markets, many of these same industries were run by a small set of oligopolists who, according to numerous sources, actively stifled competition for decades after the end of WWII. We argue that this lack of competition served to depress investment and productivity growth, which led to a movement of economic activity out of the Rust Belt and into other parts of the country (notably the "Sun Belt" in the U.S. South.)

We formalize the theory in a dynamic general-equilibrium model in which the extent of competition is what determines productivity growth. There is a continuum of goods in the economy, with some fraction produced in the "Rust Belt" and the rest produced in the "Sun Belt." The two regions differ only in the extent of competition they face. Rust Belt producers must hire workers through a labor union that demands the competitive wage for each worker plus some fraction of the surplus from production. Sun Belt producers pay only the competitive wage. In output markets, both regions face a competitive fringe with whom they engage in Bertrand competition. We assume that Rust Belt producers can "block" the fringe to some extent, while Sun Belt producers cannot. Firms in both regions have the ability to undertake investment which, at a cost, increases the productivity of any workers hired.

The main prediction of the theory is that the lesser the extent of competition in either labor or output markets in the Rust Belt, the lower its investment and productivity growth. We first illustrate this result qualitatively in a simple static version of the theory. We show there are two effects which drive the theory's prediction. The first effect is a hold-up problem which arises through the collective bargaining process. Firms in both regions make costly investments to upgrade technology. Unlike Sun Belt firms, however, Rust Belt firms must share the benefits from the technology upgrade with the union. As a result, Rust Belt firms optimally choose to invest less ex-ante than they otherwise would. The second effect comes from differences in output market competition. The inability of Sun Belt producers to block the competitive fringe gives them a stronger incentive

to invest in order to "escape the competition" (as in the work of Acemoglu and Akcigit (2011) and Aghion, Bloom, Blundell, Griffith, and Howitt (2005), among others.) This incentive is less prevalent among Rust Belt producers, and hence they invest less.

We then embed this simple static framework in a richer dynamic model in which productivity and the employment share in each region evolve endogenously over time. Because goods are gross substitutes, employment and output tend to move to the region with the highest productivity growth, as in the model of Ngai and Pissarides (2007). The main quantitative experiment takes the extent of competition over time as exogenous and computes the model's predicted shares of manufacturing employment in the Rust Belt. Discipline on the extent of competition over time comes from estimates of the Rust Belt workers' wage premiums and from estimates of markups in key Rust Belt industries. We find that the model explains roughly half the decline in the Rust Belt's manufacturing employment share.

We conclude by presenting several types of evidence supporting the theory's predictions. First, we show that investment and productivity growth in prominent Rust Belt industries were lower than those of the rest of the economy, as predicted by the theory. Second, we present historical evidence that productivity growth and technology adoption rates for Rust Belt producers tended to lag behind their foreign counterparts for much of the postwar period. Finally, we provide evidence from the cross-section of metropolitan areas in the United States that the average wage premiums paid to workers in 1950 – one sign of limited competition – are highly negatively correlated with employment growth from 1950 to 2000.

Our paper relates closely to a recent and growing literature linking competition and productivity. As Holmes and Schmitz (2010), Syverson (2011) and Schmitz (2012) argue, there is now a substantial body of evidence linking greater competition to higher productivity. As one prominent example, Schmitz (2005) shows that in the U.S. iron ore industry there were dramatic improvements in productivity following an increase in competitive pressure in the early 1980s, largely due to efficiency gains made by incumbent producers. Similarly, Bloom, Draca, and Van Reenan (2011) provide evidence that European firms most exposed to trade from China in recent years were those that innovated more and saw larger increases in productivity. Pavcnik (2002) documents that after the 1980s trade liberalization in Chile, the producers facing new import competition saw the largest gains in productivity, in part because of efficiency improvements by existing producers. A common theme with these papers and ours is that competition reduced rents to firms and workers and forced them to improve productivity. Along these lines, our work also relates closely to that of Cole and Ohanian (2004), who argue that policies that encouraged non-competitive behavior in the industrial sector during the Great Depression depressed aggregate economic activity even further.

From a modeling perspective, our work builds on several recent studies in which firms innovate in

order to "escape the competition," such as the work of Acemoglu and Akcigit (2011) and Aghion, Bloom, Blundell, Griffith, and Howitt (2005). The common theme is that greater competition in output markets encourages incumbent firms to innovate more in order to maintain a productivity advantage over potential entrants. Our model also relates to those of Parente and Prescott (1999) and Herrendorf and Teixeira (2011), in which monopoly rights reduce productivity by encouraging incumbent producers to block new technologies.

Our paper also complements the literature on the macroeconomic consequences of unionization. The paper most related to ours in this literature is that of Holmes (1998), who uses geographic evidence along state borders to show that state policies favoring labor unions greatly depressed manufacturing productivity over the postwar period. Our work also resembles that of Taschereau-Dumouchel (2012), who argues that even the threat of unionization can cause non-unionized firms to distort their decisions so as to prevent unions from forming, and that of Bridgman (2011), who argues that a union may rationally prefer inefficient production methods so long as competition is sufficiently weak.[1]

To the best of our knowledge we are the first to explore the role of competition in understanding the Rust Belt's decline. Our work contrasts with that of Yoon (2012), who argues that the Rust Belt's decline was due (in part) to rapid technological change in manufacturing, and Glaeser and Ponzetto (2007), who argue that the declines in transportation costs eroded the Rust Belt's natural advantage in shipping goods via waterways. Our paper also differs from the work of Blanchard and Katz (1992) and Feyrer, Sacerdote, and Stern (2007), who study the long-term consequences of the Rust Belt's decline in employment (rather than the root causes of the decline.) Our model is consistent with their finding that employment losses sustained by Rust Belt industries led to population outflows rather than persistent increases in unemployment rates.

[1]While our model takes the extent of competition in labor markets as exogenous, several recent studies have modeled the determinants of unionization in the United States over the last century. Dinlersoz and Greenwood (2012) argue that the rise of unions can be explained by technological change biased toward the unskilled, which increased the benefits of their forming a union, while the later fall of unions can be explained by technological change biased toward machines. Relatedly, Acikgoz and Kaymak (2012) argue that the fall of unionization was due instead to the rising skill premium, caused (perhaps) by skill-biased technological change. A common theme in these papers, as well as other papers in the literature, such as that of Borjas and Ramey (1995) and that of Taschereau-Dumouchel (2012), is the link between inequality and unionization, which is absent from the current paper.

2. Decline of the Rust Belt

In this section we present the basic fact to be explained: the decline of the Rust Belt. We show that, by a number of metrics, the Rust Belt's share of aggregate economic activity fell substantially over the post-war period.

2.1. Our Definition of the Rust Belt

While there is no widely agreed upon definition, most users of the term "Rust Belt" use it to refer to the heavy manufacturing area bordering the Great Lakes (see e.g. Blanchard and Katz (1992) and Feyrer, Sacerdote, and Stern (2007) and the references therein.) For the purposes of this paper, we define the Rust Belt to be the region encompassing Illinois, Indiana, Michigan, New York, Ohio, Pennsylvania, West Virginia and Wisconsin. This definition keeps the essence of previous use of the term and, in addition, allows us to aggregate various data sources in a consistent way.

2.2. Measuring the Decline

Our main source of data are the decadal U.S. Censuses of 1950 through 2000, available through the Integrated Public Use Microdata Series (IPUMS). The only sample restriction is to focus only on private-sector workers who are not primarily self-employed. We also draw on state-level employment data from 1970 and onward from the U.S. Bureau of Economic Analysis (BEA), and state-level value added and wage data from 1963 and onward, also from the BEA.

Figure 1 plots the Rust Belt's share of aggregate employment (grey dashed line) and share of manufacturing employment (solid black line). Both time series consist of estimates from the census data for 1950 and 1960 plus BEA state-level data in subsequent years (the census and BEA provide almost identical estimates in overlapping years). The figure shows that, by both metrics, the Rust Belt's share declined dramatically. The Rust Belt employed 43 percent of aggregate employment in 1950, and just 27 percent in 2000. In terms of manufacturing employment, the Rust Belt share was over one-half in 1950 and fell to one-third in 2000. Notably, the decline is much more dramatic from 1950 to 1980 than since 1980, in which the Rust Belt's shares of aggregate and manufacturing employment declined by only a few percentage points.

The fact that the Rust Belt's share of manufacturing employment dropped by so much suggests that the decline of the Rust Belt is not a simple story about structural change. That is, the Rust Belt's decline was not simply because the United States' manufacturing sector declined, and the Rust Belt happened to be intensive in manufacturing. The solid black line in Figure 1 clearly shows that the Rust Belt's share of employment declined *even within the manufacturing sector*. Figure 5, in the Appendix, shows that in absolute levels, manufacturing employment in the Rust Belt stayed

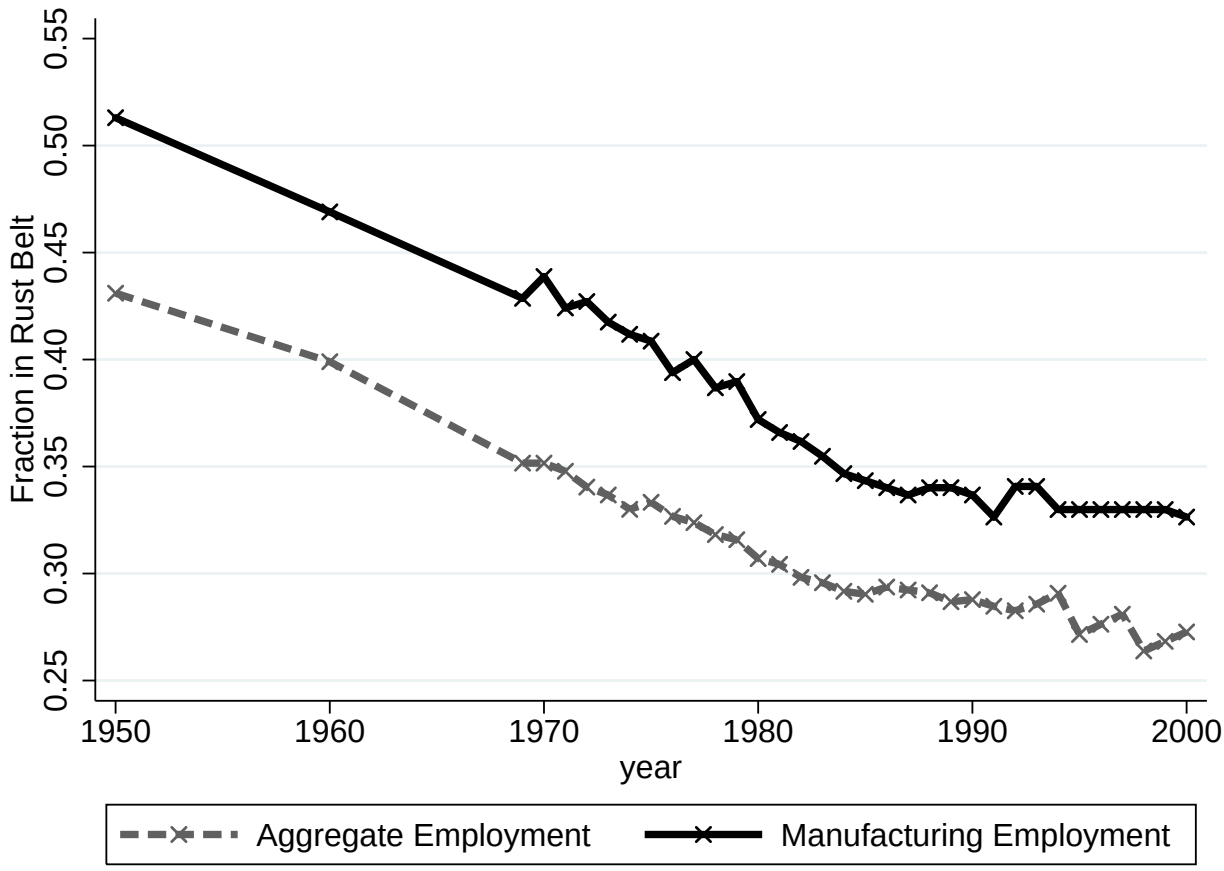

Figure 1: Fraction of Employment and Manufacturing Employment in the Rust Belt

roughly constant over this period while manufacturing employment outside the Rust Belt roughly doubled. What happened, according to these figures, is that manufacturing employment moved from the Rust Belt to elsewhere in the country.

Table 1 quantifies the decline of the Rust Belt by several other metrics. Each row describes the Rust Belt's share of U.S. economic activity in 1950 and 2000 for one particular metric, and the percentage point decline from 1950 to 2000. The first two rows reproduce the information in Figure 1 for convenience; the Rust Belt's share of aggregate employment and manufacturing employment declined by 16 percentage points and 18 percentage points, respectively.

The third row shows the decline only looking at the industries that were most prominent in the Rust Belt in the 1950s, namely steel, automobile and rubber manufacturing. The Rust Belt employed 75 percent of workers in these industries in 1950 and just 55 percent by 2000, amounting to a drop of 20 percentage points. This shows that the Rust Belt's decline was not simply a compositional change within United States manufacturing, with heavy industries such as steel, autos and rubber

Table 1: Decline of the Rust Belt by Various Metrics

	Fraction in Rust Belt		Difference
	1950	2000	1950 - 2000
Aggregate Employment	0.43	0.27	-0.16
Manufacturing Employment	0.51	0.33	-0.18
Steel, Autos and Rubber Employment	0.75	0.55	-0.20
Employment in "Cold States"	0.73	0.62	-0.11
Aggregate Value Added	0.45	0.27	-0.18
Manufacturing Value Added	0.56	0.32	-0.24

Employment shares are computed using decennial census data from IPUMS and state-level data from the BEA. Industries are classified according to IPUMS 1990 industry codes. "Cold States" are states whose average temperature is below the state average. Aggregate and manufacturing value added are imputed for 1950-1962 and 1997-2000 using annual changes in the share of wage payments by region.

declining and other manufacturing industries (e.g. high tech) rising elsewhere in the country. To the contrary, employment in steel, automobiles and rubber moved out of the Rust Belt, and even more dramatically than for manufacturing as a whole.

The fourth row of the table shows the Rust Belt's employment share among "Cold States," which we define to be all states whose yearly average temperature is below that of the average state (all Rust Belt states make the cut as Cold States.) The Rust Belt's employment share among Cold States fell from 73 percent to 62 percent, for a drop of 11 percentage points. This suggests that the Rust Belt's decline is not simply due to a rise in the availability of air conditioning, making warmer southern locales more attractive. Even among states where air conditioning was no more or less useful than in the Rust Belt, employment moved out of the Rust Belt states and into cold non-Rust-Belt states.[2]

The final two rows show the Rust Belt's share of aggregate value added and manufacturing value added. The shares in 1950 were 45 percent and 56 percent, and fell to 27 percent and 32 percent by 2000. This amounts to declines of 18 and 24 percentage points, respecitvely. The conclusion is that the Rust Belt's decline is clearly seen in value added shares as well, and in fact the decline is even more pronounced for value added than for employment.[3]

[2]This finding is consistent with the work of Holmes (1998), who looks at counties within 25 miles of the border between right-to-work states and other states and finds that countries in the right-to-work states had much higher employment growth rates (since the end of WWII) than their counterparts on the other side of the border. Given that there are essentially no differences in temperature between these sets of counties, Holmes (1998) argues that the differences in outcomes must be due to differences in state policies, most notably right-to-work laws.

[3]One positive result of the Rust Belt's drop in manufacturing is that the environment improved. Kahn (1999) shows that regions with the biggest declines in manufacturing activity tended to see the largest improvements in air quality.

3. Lack of Competition in the Rust Belt

In this section we show that one salient characteristic of the Rust Belt was a relatively low degree of competition in labor and output and markets for several decades after the end of WWII. Labor markets in the Rust Belt were dominated by powerful labor unions in most of the prominent Rust Belt industries. Output markets were characterized by close-knit oligopolists in many industries that, by many metrics, faced very low competitive pressure from the outside. Around the 1980s, however, competitive pressure increased, as output markets drew new competition from abroad and new entrants at home, and labor markets witnessed a drop in the influence of unions.

3.1. Lack of Competition in Labor Markets

It is widely known that unions dominated labor markets in many Rust Belt manufacturing industries. The two largest and most powerful unions in the United States at the time were the United Steelworkers (USW) and United Auto Workers (UAW). Roughly two thirds of all auto workers were members of the UAW, while an only slighter smaller fraction of steel workers were members of the USW.[4] The majority of steel and auto workers were employed in the Rust Belt for decades after the end of WWII. According to the U.S. Bureau of Labor Statistics, of the top ten most unionized states in 1974, seven were Rust Belt states, as were four of the top five (Michigan, West Virginia, New York and Pennsylvania.)[5]

It is also well established that these unions extracted great concessions from their employers and enjoyed substantial rents. Figure 2 shows one simple metric of these rents: the ratio of average wages in the Rust Belt to average wages in the rest of the country. The dashed gray line shows the relative wages for all workers, and the solid black line shows the relative wages for manufacturing workers. From 1950 to 1980 the average wage was at least 10 percent higher in the Rust Belt than in the rest of the country, and reached 15 percent (among manufacturing workers) by 1980.[6]

Industry histories provide more direct evidence of the types of rents enjoyed by workers in these unions. Ingrassia (2011) and Vlasic (2011) provide numerous examples of various concessions extracted from the "Big Three" auto producers of Ford, General Motors and Chrysler from WWII. By 1973, a UAW worker could earn "princely sums" working on production or other union-created

[4]These figures are for 1970 and come from BLS Bulletin 1937 Appendix D. The UAW and USW also had large membership rates in a diverse set of other manufacturing industries (Goldfield, 1987).

[5]BLS Bulletin 1865 and BLS Bulletin 1370-12. Unionization rate are the percent of all non-agricultural employment that is covered under a collective bargaining agreement.

[6]The ratio of average wages, while a crude measure of wage premiums, is similar to the estimated "Rust Belt" dummy we find when regressing individual-level wages on education, potential experience and other controls. More generally, the ratio of average wages is in the same range as the estimated union wage premium documented in a long literature (see e.g. Blanchflower and Bryson (2004) for a review.)

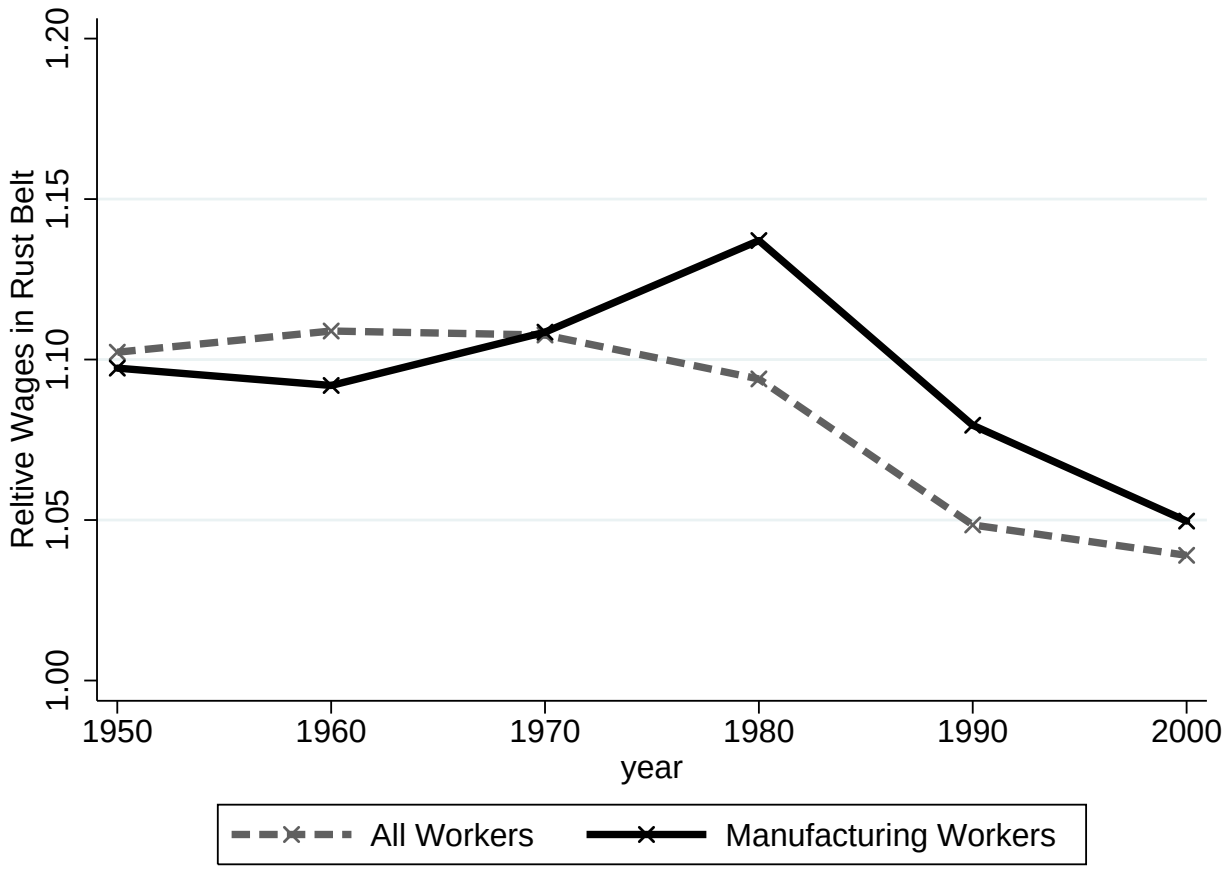

Figure 2: Relative Wages of Rust Belt Workers

jobs, such as serving on the plant "recreation committee." In many cases workers could retire with full benefits as early as age 48 (Ingrassia, 2011, pp. 46, 56). In steel, Tiffany (1988) states that in 1959, average hourly earnings for steel workers were more than 40 percent higher than the all-manufacturing average in the United States, and points to this premium as evidence that steel workers earned rents (p. 178). Evidence of non-wage rents in steel abound, such as clauses in various steelworker contracts that guaranteed that the steel mills would be shut down on the first day of deer hunting season (see e.g. Hoerr (1988)).

Figure 2 also provides an indication that union power began to decline during the 1980s. Relative wages in the Rust Belt fell from roughly 12 percent above other workers to just 4 percent above by 2000. Not coincidentally, union membership dropped steadily over this period. Figure 6 (in the Appendix) shows the unionization rate for the country as a whole using data from Goldfield (1987), and in the Rust Belt, using the state-level unionization database of Hirsch and Macpherson (2003)). In 1980, the first year of available disaggregated data, 30 percent of the Rust Belt workforce was unionized. By 2000, the unionization rate in the Rust Belt was below 20 percent.

3.2. Lack of Competition in Output Markets

In output markets served by the prominent Rust Belt industries, production was dominated by just a few firms for most of the postwar period. The largest three steel producers – U.S. Steel, Bethlehem Steel, and National Steel – had virtually the entire domestic market right after WWII and at least half the country's total steel capacity from the end of through 1980 (Crandall, 1981; Tiffany, 1988). The Big Three auto producers accounted for 90 percent of automobile sales in the United States in 1958, and at least 75 percent until around 1980 (Klier, 2009). A similar dominance pertained to the four largest rubber tire producers, who had at least 90 percent of the market in every year from 1950 to 1970.[7]

In each of these industries, there is evidence that the few producers behaved non-competitively. Adams and Brock (1995, p. 94) describe the big Steel producers as having had "virtually unchallenged control of a continent-size market," which led to a "well-honed system of price leadership and follower-ship" with U.S. Steel as the leader. That the big steel producers appeared to cooperate in pricing is echoed in numerous other industry studies as well.[8] Similarly, Ingrassia (2011, p. 29) describes the automobile industry as being a "model of corporate oligopoly" throughout the 1950s, 1960s and 1970s, with General Motors playing the role of the price leader.[9]

Both steel and autos, as well as rubber, were accused on multiple occasions of explicit collusion. In 1959, the Federal Trade Commission (FTC) charged fifteen rubber manufacturers with agreeing on common list prices and discounting policy (French, 1991).[10] Tiffany (1988) describes several similar instances in Steel, and on several occasions management at the big steel firms were called in front of congress to explain their lack of competition in pricing.[11] In the auto industry, the U.S. Justice Department at different points charged Ford and GM with collusion and charged the Big

[7] These four were Goodyear, Firestone, U.S. Rubber and Goodrich. All four were located in Akron, Ohio, once known as the "Rubber Capital of the World."

[8] Hudson and Sadler (1989) for example write that "in 1948 the industry .. [began] a system whereby all firms automatically followed US Steel's lead in pricing. During this era, therefore, companies were assured of a comfortable profit margin and faced little incentive to seek out new, more profitable, locations; nor did they do so."

[9] Adams and Brock (1995, p. 78) write that "the prices adopted by the Big Three [auto manufacturers] appear at times to represent the outcome of a tacit bargain arrived at through a delicate process of communication and signaling.... Once they have revealed their hands to one another, then they announce their final prices, which, not surprisingly, tend to be quite similar."

[10] The FTC claimed that the rubber manufacturers had revived the cooperative policies granted to them in the 1930s by the National Industrial Recovery Act (which was later outlawed). The manufacturers agreed to "cease and desist" without admitting any wrongdoing. See French (1991, p. 95).

[11] For example, in 1957 the Senate's antitrust committee directly accused the steel industry of anticompetitive pricing behavior, and called industry leaders to testify for six days. In a telling exchange between Senator Estes Kefauver and U.S. Steel chairman Roger Blough, Kefauver asked why all the major steel companies had the same price. Blough responded: "...if we offer to sell steel to a customer at the same price as a competitor offers to sell to the customer, that is very definitely a competitive price." According to Tiffany (1988), Kefauver and the rest of committee were thoroughly unconvinced, yet no punishment was ever sought for any steel producer.

Three with conspiring to eliminate competition (Adams and Brock, 1995, p. 87).

Several types of evidence suggest that competitive pressure picked up starting in the 1970s and 1980s, as the cost of imports from abroad plummeted and new firms entered the domestic markets for goods formerly supplied almost exclusively by Rust Belt producers. In each of the steel, auto and rubber industries, concentration ratios fell substantially starting in the 1970s and 1980s. In autos, the Big Three' currently have less than half the domestic market, with even lower figures in steel and rubber (Tiffany, 1988; French, 1991). Estimates of markups paint a similar picture, at least where such estimates exist. In the steel industry, Collard-Wexler and De Loecker (2012) estimate markups of on average 25 percent over the period 1967 through 1987 for the integrated segment of the steel industry (most of which was in the Rust Belt).[12] In the period since 1987 their estimated markups averaged just 13 percent.[13]

4. Simple Model

In this section we present a simple model which illustrates the main components of the theory. The model links the extent of competition in labor and output markets to investment and hence productivity growth. The model predicts that less competition in either market leads to lower investment.

4.1. Environment

There is a continuum of intermediates, indexed by j, which are combined to produce a final good. The production function for the final good is given by

$$Y = \left(\int_0^1 y(j)^{\frac{1}{2}} di \right)^2 \tag{1}$$

where any two intermediates have elasticity of substitution two between them. The final good can either be consumed or used for investment. Intermediates $j \in [0, \frac{1}{2})$ are produced in the "Rust Belt," and intermediates $j \in [\frac{1}{2}, 1]$ are produced in the "Sun Belt." The two regions differ in the nature of their competition in labor markets and output markets (described below). Each intermediate j is produced in an industry that has a single "leader" firm and, in the Sun Belt region, a competitive

[12] These numbers are consistent with estimated markups in the auto industry over this period. Berndt, Friedlaender, and Chiang (1990) estimate markups for Ford, GM and Chrysler over the period 1959 through 1983. Taking an average of the three firms and the years in their sample, their estimated markups are 21 percent.

[13] The evidence of Schmitz (2005) and Dunne, Klimek, and Schmitz (2010) shows that the early 1980s were a time when competitive pressure in the United States increased substantially in at least two important industries: iron ore and cement. In both industries one impetus for the increased competition was a lowering of transportation costs for foreign competitors.

fringe (also described below).

Production of intermediates takes place in two stages. In the first stage, each leader firm enters with productivity level, denoted z, and chooses their "technology upgrade," denoted x. Upgrading technology by x requires a cost $I(x)$, where $I(\cdot)$ is strictly convex and is such that $I(0) = 0$. Importantly, the technology upgrade is irreversible once it has been made, and hence the investment is sunk. One can think of z as technology capital, using the language of McGrattan and Prescott (2010), which they define as the "accumulated know-how from investments in R&D, brands and organizations," and $I(x)$ as the investments themselves.

After investment, the productivity of leader j becomes $z(1+x(j))$, and the production function becomes

$$y(j) = z[1+x(j)]\ell(j) \tag{2}$$

where $y(j)$ and $\ell(j)$ represent the leader's output and labor input.

In the second stage, firms decide how much labor to hire and what price to charge, given their production function, (2). In the Sun Belt, leader firms must Bertrand compete with the competitive fringe. Thus, leader firms there pick the optimal price taking into consideration the fringe. In the Rust Belt, we assume the leader firms get to "block" the fringe from operating. Thus, leaders firms in the Rust Belt face no competition from the fringe and set an optimal monopolist markup.[14]

The labor market in the Rust Belt is dominated by a single labor union that is the sole supplier of labor services. In order to produce any output, Rust Belt firms must not only pay each worker hired the competitive wage (normalized to one), but must also pay a fraction of their surplus to the labor union. The fraction of the surplus paid to the union is determined by Nash Bargaining, with the union's bargaining weight given by β, and the union's share of the surplus (rents) denoted R. The labor market in the Sun Belt is competitive, in contrast, and each worker earns the competitive wage.

The household has a unit measure of members, each of which is endowed with one unit of time that they supply inelastically to the labor market. Jobs in the Rust Belt are rationed, and only a fraction of household members (chosen at random by the firms) may supply labor to the Rust Belt. The household pools workers' labor earnings plus profits from the firms, and spends all its income on the final good. Formally, the household's budget constraint is

$$P \cdot C = 1 + R + \int_0^{\frac{1}{2}} \Pi_R(j)dj + \int_{\frac{1}{2}}^1 \Pi_S(j)dj \tag{3}$$

[14] In the richer dynamic model to follow, we allow the extent of blocking, and hence the extent of competition in output markets, to be governed by a parameter.

where P is the price of the final good, C is the quantity of the final good purchased for consumption, $1+R$ is the labor earnings plus the rents earned by workers in the Rust Belt, and $\Pi_R(j)$ and $\Pi_S(j)$ are profits earned by intermediate firms in the Rust Belt and Sun Belt.

4.2. Sun Belt Producer's Problem

Consider now the first-stage (investment) problem of one individual producer j in the Sun Belt. Dropping the j index for expositional purposes, the producer's problem is

$$\Pi_S = \max_{x_S} \left\{ \tilde{\pi}_S(x_S) - I(x_S) \right\} \tag{4}$$

where $\tilde{\pi}_S(x_S)$ represents the *quasi-rents*, or surplus, earned in the second stage. The second-stage problem is to pick prices and labor input to maximize these quasi rents:

$$\tilde{\pi}_S(x_S) = \max_{p_S,\, \ell_S} \left\{ p_S y_S - \ell_S \right\} \tag{5}$$

subject to

$$y_S = z[1+x_S]\ell_S, \quad \text{and}$$

$$y_S = X \cdot P \cdot [p_S]^{-2}. \tag{6}$$

Equation (6) is the standard demand function associated with a CES production function. Variables X and P represent the (endogenous) total spending on all goods by the household and firms, and the aggregate price index.[15] Since Sun Belt leaders must Bertrand compete with the competitive fringe, it follows that they limit price the fringe, charging a price of $p_S = 1/z$.[16]

To understand better how the Sun Belt producers operate, it is useful to rewrite their first-stage problem after incorporating the optimal limit-pricing behavior. It is

$$\Pi_S = \max_{x_S} \left\{ x_S \ell_S(x_S) - I(x_S) \right\} \tag{7}$$

where $\ell_S(x_S) = X \cdot P \cdot z[1+x_S]^{-1}$. One can then see how investment is key to earning any profits at all; if the leader doesn't invest, she cannot price below the fringe, and hence earns no profits. More generally, the presence of the fringe provides an incentive for the leader to lower their marginal cost below that of the fringe so as to price further above marginal cost and increase profits. This has what the literature has referred to as the escape-competition effect; see e.g. Acemoglu and

[15] These are given by $X = \int_0^{\frac{1}{2}} p_R(j) y_R(j) dj + \int_{\frac{1}{2}}^1 p_S(j) y_S(j) dj$ and $P = \left[\int_0^{\frac{1}{2}} p_R(j)^{-1} dj + \int_{\frac{1}{2}}^1 p_S(j)^{-1} dj \right]^{-1}$.

[16] If investment among Sun Belt producers is sufficiently high in equilibrium, specifically if $x_S > 1$, then Sun Belt producers choose a standard monopolistic markup. For expositional purposes we focus here on the case where $x_S \leq 1$.

Akcigit (2011) and Aghion, Bloom, Blundell, Griffith, and Howitt (2005).

4.3. Rust Belt Producer's Problem

The Rust Belt producers' problem differs from the Sun Belt producers' problem in two ways. First, in output markets, the Rust Belt gets to block the competitive fringe and set a standard monopolist markup. Second, in labor markets, the Rust Belt must hire labor through a union with collective bargaining rights. The union supplies labor in exchange for the competitive wage plus a share of the firms' surplus after producing.

4.3.1. Collective Bargaining

Consider first the second-stage problem, once the technology upgrade, x_R, has been made. The quasi-rents of a given Rust Belt firm are

$$\tilde{\pi}_R(x_R) = \max_{p_R, \ell_R} \left\{ p_R y_R - \ell_R \right\} \quad \text{where} \tag{8}$$

$$y_R = z[1 + x_R]\ell_R, \quad \text{and}$$

$$y_R = X \cdot P \cdot [p_R]^{-2}. \tag{9}$$

These quasi-rents are defined identically to those of the Sun Belt producers. The difference is that Rust Belt firms must bargain over the quasi-rents with the union. We assume that the union and each producer split the surplus according to Nash Bargaining, with the unions' bargaining weight represented by $\beta \in [0,1]$. The solution to the bargaining problem yields the standard result that the union receives a share β of the quasi-rents, with the firm taking the other $1-\beta$.

4.3.2. Investment and Production

Now consider the first-stage problem of the Rust Belt producer. Given the bargaining solution above, the problem becomes:

$$\Pi_R(j) = \max_{x_R} \left\{ (1-\beta)\tilde{\pi}_R(x_R) - I(x_R) \right\}. \tag{10}$$

In other words, firms pick investment to maximize their share of the quasi-rents minus their cost of investment. One can easily show that the first-order condition characterizing a Rust Belt producer's choice of investment is

$$(1-\beta)\tilde{\pi}'_R(x_R) = I'(x_R). \tag{11}$$

This equation shows that investment is lower the higher is β. This result arises because the bargaining problem involves a quintessential *hold-up problem.* Since the investment decision cannot be reversed once it has been made, the workers can hold up the firm and extract a larger share of the surplus ex-post.[17] This effect is not present in the Sun Belt since producers there do not bargain with a union.

A second key difference is that Rust Belt producers do not face a competitive fringe, and simply choose their optimal price (taking prices of the other goods as given.) As is standard, these firms choose a price which gives them a constant markup (in this case of 100 percent) over marginal cost:

$$p_R = 2(z[1+x_R])^{-1}. \tag{12}$$

It is useful to re-write the Rust Belt producer's first-stage (investment) problem incorporating their optimal price as

$$\Pi_R = \max_{x_R} \left\{ (1-\beta) \cdot \ell_R(x_R) - I\left(x_R\right)] \right\} \tag{13}$$

subject to $\ell_R(x_R) = X \cdot P \cdot z[1+x_R]^{-1}$. Here, the firm earns a constant $1-\beta$ units of output per unit of labor input hired, reflecting the constant markup over marginal cost charged by the Rust Belt firm. This is true even if the firm does no technology upgrading at all. Thus, unlike the Sun Belt's equivalent problem in (7), the escape-competition effect is absent. The Rust Belt firms' rationale for innovation is that a more efficient production technology increases demand for their variety.

4.4. Optimal Investment in Equilibrium

An equilibrium of the economy is a set of quantities and prices such that households and producers solve their problems taking prices (other than their own) as given, all firms in each region choose the same prices and quantities, and markets clear. The main result of this simple model is as follows.

Proposition 1 *Equilibrium investment is lower in the Rust Belt region.*

The proof is in the Appendix. To gain some intuition for the result, consider first the case when parameters are such that $x_S > 1$. One can think of this as being the case when investment costs are "sufficiently low." In this case, the Sun Belt producers are so much more productive than the competitive fringe that they choose to set a standard monopoly markup, just like Rust Belt

[17] Van Reenen (1996) provides concrete evidence that workers do in fact capture a share of the surplus from innovations by their firms. Using a rich panel of firms of the United Kingdom, he shows firms that innovate tend to pay higher wages with a lag of roughly three years after innovating. He estimates that workers in innovating firms capture on average 20% to 30% of the quasi-rents generated by innovation.

producers. One can combine the firms' first order conditions to show that optimal investment in equilibrium must satisfy the following equation:

$$I'(x_R) = (1-\beta)\, I'(x_S). \tag{14}$$

It follows therefore that $x_R < x_S$, since $\beta > 0$ and $I(\cdot)$ is convex. Here, the difference in investment results only from the fact that labor manages to extract a fraction of the surplus (positively related to β) from Rust Belt producers. Absent this non-competitive behavior in labor markets, i.e. when $\beta = 0$, investment is identical in the two regions.

Consider next the case when parameters are such that $x_S < 1$. One can think of this as the case when investment costs are sufficiently high. Now Sun Belt producers limit price the competitive fringe, while Rust Belt firms choose the standard monopolist markup.[18] In addition, Rust Belt firms still must bargain with labor over the surplus. Combining the firms' first order conditions this time yields:

$$I'(x_R) = (1-\beta)\left(\frac{1+x_S}{2}\right)^2 I'(x_S). \tag{15}$$

In this case it also must be true that $x_R < x_S$. There are now two reasons for the difference in equilibrium investment. As before, the $1-\beta$ term arises from the fact that the Rust Belt firms get to keep less than the total proceeds from investment. In addition, the $\left(\frac{1+x_S}{2}\right)^2$ term arises from the differences in output market competition, and this term is less than one as long as $x_S < 1$ in equilibrium, which is true if and only if the Sun Belt firms are actually limit pricing in equilibrium. If so, Rust Belt firms get to charge a higher markup even when innovating relatively less, while Sun Belt firms innovate more to escape the competition.

[18] Bernard, Eaton, and Jensen (2003) have a similar result, where the most productive producer either sets a standard monopolist markup if it is much more productive than other firms, or limit prices the second most productive if the two have more similar productivty levels.

5. Dynamic Model

We now embed the main features of the simple static model into a richer dynamic model that can be used for quantitative experiments. The dynamic model differs in several main ways from the static model. First, firm productivity and employment shares by region evolve endogenously over time. Second, the extent of output-market competition is governed by a parameter, which allows more flexibly in the quantitative work. Third, the extent of competition in output markets is determined not just by the escape-competition effect, but by an opposing *Schumpeterian effect*, which has been emphasized by the literature. Thus, whether greater competition in output markets leads to lower or higher investment in equilibrium is not predetermined in the model, but rather driven by the data used to discipline the model.

5.1. Environment

Preferences of the household are given by

$$U = \sum_{t=0}^{\infty} \delta^t C_t, \tag{16}$$

where δ is the discount factor and C_t is consumption of a final good. The final good is produced using the CES production function

$$Y_t = \left(\int_0^1 q_t(j)^{\frac{\sigma-1}{\sigma}} dj \right)^{\frac{\sigma}{\sigma-1}}, \tag{17}$$

where σ is the elasticity of substitution between any pair of intermediates in the economy. We assume that $\sigma > 1$, which implies that the intermediates are gross substitutes. As before, the final good can be used for both consumption and investment, and each intermediate is produced by a single producer located in one of two regions: the Rust Belt and the Sun Belt. The measure of goods produced in the Rust Belt is $\lambda \in (0,1)$, while the measure of goods produced in the Sun Belt is $1-\lambda$. Just as in the simple model, the production of each good requires a single input, labor, and the wage is normalized to unity each period.

Each period is divided into two stages. In the first stage, the intermediate firms decide how much to upgrade their technology, denoted by x_t. In the second stage, the firms decide how much labor to hire and what price to charge, and then produce. As before, Rust Belt producers bargain with unions over their surplus after producing, with bargaining weight β_t for the union and $1-\beta_t$ for the firm. Note that the bargaining weight may change over time, as the t subscripts indicate.

Producers in both regions face a competitive fringe each period. In the Sun Belt, the fringe enters

with productivity $\phi z_{S,t}$, where $z_{S,t}$ is the initial productivity among Sun Belt producers, and the parameter $\phi > 0$ governs how effectively the fringe catches up to the leader firms each period. In the Rust Belt, the fringe begins the second stage with productivity $\phi z_{R,t}(1-\mu_t)$. The parameter μ_t stands for the extent of "monopoly power" in output markets, and captures the ease with which incumbents can block entry by potential challengers. As μ_t goes to one, the extent of output-market competition in the Rust Belt is minimized, as in the simple model. As μ_t goes to zero, imperfections in output market vanish, as in the Sun Belt. One can think of μ_t as arising from policies which protect incumbent producers, such as emphasized by Parente and Prescott (1999) and Herrendorf and Teixeira (2011), though we interpret the extent of competition broadly as any reason the leaders would face immediate competitors with high costs.

The extent of competition each period is governed by state $\theta_t \equiv (\beta_t, \mu_t)$, which takes on one of three values. Formally, $\theta_t \in \{\theta_H, \theta_L, \theta_C\}$, where θ_H represents a *high-distortion* state, θ_L represents a *low-distortion* state, and θ_C stands for a *competitive* state. The transition from one state to another is governed by the following transition matrix.

Table 2: Transition Probabilities Between States

	θ_H	θ_L	θ_C
θ_H	$1-\varepsilon$	ε	0
θ_L	0	$1-\varepsilon$	ε
θ_C	0	0	1

From either the high-distortion or low-distortion states, with probability ε the economy transitions to a more competitive state. With probability $1-\varepsilon$ the economy states in the same state. The competitive state θ_C is absorbing.

5.2. Static Firm Problem

The firms' static profit maximization problem is similar to the one laid out in the simple static model of the previous section. Still, we spell it out completely here for clarity. In the first stage, the firm decides how much to invest. In the second stage, the firms decides what price to set and how much labor to hire in order to maximize their quasi-rents. Clearly, forward-looking producers anticipate the quasi-rents in stage two associated with any given investment decision. So let us describe the firm's problem starting with stage two.

Consider a Sun Belt firm (dropping t subscripts) who enters the period with productivity z_S and has chosen technology upgrade x_S. Assume that all the other Sun Belt firms have productivity $\tilde{z}_S$ and have chosen upgrade $\tilde{x}_S$, which could be equal to z_S and x_S (and will be in equilibrium). Finally,

assume that all Rust Belt producers have productivity $\tilde{z}_R$ and have chosen $\tilde{x}_R$. To keep the notation tidy, we define $Z_S \equiv (z_S, \tilde{z}_S, \tilde{z}_R)$ and $X_S \equiv (x_S, \tilde{x}_S, \tilde{x}_R)$. Whenever possible, we also drop the firm label $j \in [0,1]$. The static profit maximization problem of the Run Belt firm is to maximize the quasi-rents:

$$\tilde{\pi}_S(Z_S, X_S; \theta) = \max_{p_S,\, \ell_S} \Big\{ p_S y_S - \ell_S \Big\} \tag{18}$$

subject to $y_S = z_S[1+x_S]\ell_S$ and $y_S = X \cdot P^{\sigma-1} \cdot p_S^{-\sigma}$, which are the production function and standard demand function under CES preferences. As before, X and P represent total spending on all goods by the household and the aggregate price index, respectively:

$$X = \int_0^{\lambda} p_R(j) q_R(j) dj + \int_{\lambda}^{1} p_S(j) q_S(j) dj$$
$$P = \Big[\int_0^{\lambda} p_R(j)^{1-\sigma} dj + \int_{\lambda}^{1} p_S(j)^{1-\sigma} dj \Big]^{\frac{1}{1-\sigma}}.$$

Since Sun Belt leaders must Bertrand compete with the competitive fringe, it follows that they limit price the fringe and charge $p_S(i) = \frac{1}{\phi z_S}$.[19]

Now consider a Rust Belt firm who enters the period with productivity z_R and has chosen investment level x_R, while all other Rust Belt producers have productivity $\tilde{z}_R$ and investment $\tilde{x}_R$. Assume that all Sun Belt producers have productivity $\tilde{z}_S$ and have chosen investment $\tilde{x}_S$. As we did for the Sun Belt, let us define $Z_R \equiv (z_R, \tilde{z}_R, \tilde{z}_S)$ and $X_R \equiv (x_R, \tilde{x}_R, \tilde{x}_S)$. Quasi-rents of the Rust Belt are given by

$$\tilde{\pi}_R(Z_R, X_R; \theta) = \max_{p_R,\, \ell_R} \Big\{ p_R y_R - \ell_R \Big\} \tag{19}$$

subject to $y_R = z_R[1 + x_R]\ell_R$ and $y_R = X \cdot P^{\sigma-1} \cdot p_R^{-\sigma}$. The additional argument in the Rust Belt producer's profit function, μ, reflects the difference in the limit price compared to a Sun Belt producer.

5.3. Dynamic Firm Problem

We now consider the dynamic problem of the firms. The Bellman equation that describes a Sun Belt producer's problem is:

$$V_S(Z_S; \theta) = \max_{x_S} \Big\{ \tilde{\pi}_S(Z_S, X_S) - I(x_S, Z_S) + \delta \mathbb{E}\Big[V_S\big(Z_S; \theta'\big) \Big] \Big\} \tag{20}$$

[19] For expositional purposes we focus on the case where investment in equilibrium is "sufficiently low" such that it is optimal for Sun Belt producers to limit price the fringe. More generally, they either limit price or set a standard monopolist markup, depending on how much investment they undertake in equilibrium.

where $Z_S' = \left(z_S(1+x_S), \tilde{z}_S(1+\tilde{x}_S), \tilde{z}_R(1+\tilde{x}_R)\right)$, and the expectations are over θ', tomorrow's state of competition. The Sun Belt producer picks the amount of investment each period to maximize quasi rents minus investment costs plus the expected discounted value of future profits.

Analogously, the Rust Belt producer's Bellman equation is:

$$V_R(Z_R;\theta) = \max_{x_R}\left\{(1-\beta)\tilde{\pi}_R(Z_R,X_R,\theta) - I(x_R,Z_R) + \delta\mathbb{E}\left[V_R\left(Z_R';\theta'\right)\right]\right\} \tag{21}$$

where $Z_R' = \left(z_R(1+x_R), \tilde{z}_R(1+\tilde{x}_R), \tilde{z}_S(1+\tilde{x}_S)\right)$. The Rust Belt producer picks its technology upgrade to maximize its share of quasi rents minus investment costs, plus the expected discounted value of future profits. Its share is $1-\beta$, which is determined by the Nash bargaining.

Finally, letting $i \in \{R,S\}$ denote the region, we assume that the investment cost function is

$$I(x_i,Z_i) = x_j^{\gamma}\frac{\overline{c}\, z_i^{\sigma-1}}{\lambda\tilde{z}_R^{\sigma-1} + (1-\lambda)\tilde{z}_S^{\sigma-1}} \tag{22}$$

for $Z_i = (z_i, \tilde{z}_i, \tilde{z}_{-i})$, $\gamma > 1$, and $\overline{c} > 0$. One desirable property of this cost function is that investment costs are increasing and convex in x. Moreover, the further the firm lags the "average" productivity level in the economy the cheaper it is to upgrade the current technology z_i. A second desirable property, as we show later, is that this cost function delivers balanced growth when distortions in labor and output markets are shut down.

5.4. Dynamics in the Competitive State

In the competitive state, $\beta = \mu = 0$ for the current period and all future periods. Analyzing the competitive state is convenient for gaining intuition, as the dynamics are particularly clean when there is no imperfect competition in either region. To see this, define the balanced growth path to be a situation where $x_R = x_S = x$ each period. Then, one can show that three things are true along the balanced growth path. First, x is given as the solution to a single equation in one unknown. Second, the ratio z_R/z_S is constant from one period to the next. Third, the Rust Belt's employment share is constant from one period to the next.

These properties of the balanced growth path are useful for several reasons. First, they illustrate that in the competitive state, both regions grow at the same rate. This implies that the decline of the Rust Belt can only come about in the model from imperfect competition there (and not, simply differences in the productivity states of the two regions). Second, the properties are useful in calibrating the model, as the properties of the model in the competitive state can largely be solved by hand. This makes the long run properties of the model transparent and tractable.

5.5. Dynamics under Imperfect Competition

We now consider when the state of competition is either θ_H or θ_L. As will be documented quantitatively in the following section, when plausibly calibrated, the model in either of these states predicts that investment (and productivity growth) is lower in the Rust Belt than the Sun Belt. One can show that if investment is lower in the Rust Belt than the Sun Belt in the current period, then the employment share in the Rust Belt declines between the current and following period. The reason is simple. Less investment means that the relative price of the Rust Belt's goods rises, and because goods are gross substitutes consumers demand relatively more of the cheaper Sun Belt goods. Thus, as in Ngai and Pissarides (2007), employment flows to the Sun Belt.

Two effects now determine the link between competition in output-market competition and investment. The first is the escape-competition effect described in the simple model. All else equal, the stronger is the competitive fringe today (i.e. the lower is μ_t), the more incentive leader firms have to invest today to lower their costs. The second effect is now the so-called Schumpeterian Effect (see e.g. Aghion, Bloom, Blundell, Griffith, and Howitt (2005) and the references therein.) This effect says that the greater is the catch-up of the competitive fringe tomorrow (i.e. the lower is μ_{t+1}), the *less* incentive leader firms have to invest today, since they will get to enjoy the benefits of having lower costs for fewer periods. Which effect dominates is not predetermined in the model, but will be determined by the data used in the parameterization procedure (and the procedure itself) in the section to follow.

6. Quantitative Analysis

We now turn to a quantitative analysis of the dynamic model, where we ask how large of a decline in the Rust Belt's manufacturing employment share the model predicts over the period from 1950 to 2000. We calibrate the extent of competition faced by Rust Belt producers using evidence on wage premiums and markups. We find that the model explains approximately half the drop in the Rust Belt's manufacturing employment compared to the data.

6.1. Parameterization

We set a model period to be five years. We set the discount rate to $\delta = 0.96^5$ so as to be consistent with a 4 percent annual interest rate. For the elasticity of substitution we set $\sigma = 2.3$ based on the work of Broda and Weinstein (2006), who estimate substitution elasticities between a large number of goods at various levels of aggregation. Their median elasticity estimate is at least 2.3, depending on the time period and level of aggregation. We note that ours is a conservative choice in that higher values of σ will lead to an even greater predicted decline in the Rust Belt's employment

share. Next, we normalize the initial productivity states to be $z_S = z_R = 1$, and set the initial state of competition to be θ_H, reflecting the evidence (of Section 3) that competitive pressure was at its lowest in the 1950s.

We calibrate the remaining parameters jointly. These are: ϕ, which governs the catch-up rate of the fringe; λ, which pins down the share of goods produced in the Rust Belt; γ, which is the curvature parameter in the investment-cost function; and $\overline{c}$, which is the (linear) scale parameter in the cost function.

We choose these values to match four moments of the data. The first is an average markup of 10 percent in the Sun Belt, which is consistent with what Collard-Wexler and De Loecker (2012) estimate for 2000 among minimill steel producers (most of which were located in the U.S. South.) The second is an initial employment share of 51 percent in the Rust Belt, to match the manufacturing employment share in the data in 1950. The third is an investment-to-GDP ratio of 5 percent, which McGrattan and Prescott (2010) report as the average sum of investments in R&D, advertising and organization divided by GDP. The fourth and final moment is a long-run growth rate (in the competitive state) of 2 percent per year.

Table 3: Targeted Wage Premiums and Markups

	Wage Premium	Markup
θ_H	0.12	0.22
θ_L	0.04	0.14

We also match values of μ and β in states θ_H and θ_L jointly in the calibration procedure. These are chosen to match the estimated markups over the period described in Section 3, and the estimated wage premiums plotted in Figure 2. The targets are listed in Table 3. The targets for θ_H are supposed to capture the values from the period between 1950 to 1980, while the targets for θ_L are supposed to represent the period afterwards, when competitive pressure rose.

We calibrate the model for two different assumptions about ε, the probability that the state of competition changes. In the "optimistic" scenario we assume that $\varepsilon = \frac{1}{8}$. This implies that model firms expect to stay 8 periods, or 40 years, in each state of competition before moving to the next one. In other words, Rust Belt firms in 1950 expect to stay in state θ_H until 1990, and then in state θ_L until 2030, before finally switching to θ_C. In the "pessimistic" scenario we assume that $\varepsilon = \frac{1}{2}$. This implies that firms expect to stay just two periods, or a decade, in each state of competition. Thus, firms in 1950 expect to stay in θ_H until 1960 and then θ_L until 1970 before switching to θ_C. While it is hard to know just what firms were expecting, we suspect that their expectations must have been somewhere in the range of these two scenarios.

In either scenario, we impose that the economy moves from θ_H to θ_L in 1985, consistent with evidence of Section 3, and then from θ_L to θ_C in 2000. The idea is that, regardless of what firms expected, competitive pressure did pick up in 1985. The choice of moving to the competitive state in 2000 is based in part on the data, which show the lowest markups and wage premiums at the end of the period, and in part based on convenience: what we assume post 2000 has little baring on the model's predictions for 1950 to 2000, and the model is most tractable in the competitive state.

The parameter values implied by the calibration (under the pessimistic scenario) are $\phi = 1.02$, $\lambda = 0.57$, $\gamma = 1.7$ and $\overline{c} = 2.9$. The bargaining power parameters are $\beta_H = 0.320$ and $\beta_L = 0.168$ in 1985. The monopoly power parameters are $\mu_H = 0.141$ and $\mu_L = 0.071$.

6.2. Quantitative Results

Figure 3 displays the model's predictions for the manufacturing employment share in the Rust Belt from 1950 to 2000. Several points are worth noting from the figure. First, in both scenarios for expectations, the model predicts a large decline in the Rust Belt's employment share, as in the data. The model predicts a drop of 7 and 10 percentage points in the two scenarios, from 51 percent down to 44 and 41 percent. In the data, the drop is 18 percentage points, from 51 percent down to 33 percent. By this metric, the model explains between 40 and 54 percent of the decline of the Rust Belt.

The second feature worth noting is that the model's predicted decline is more pronounced between 1950 and 1980, as in the data. The model predicts a drop of 7 and 9 percentage points in this earlier period, while the actual drop was 15 percentage points (from 51 down to 36 percent). In the subsequent two decades, from 1980 to 2000, the Rust Belt's employment share declined just three percentage points in the data. The model also predicts a less pronounced drop over this period equalling less than one percentage point in each of the two scenarios.

Why does the model predict a sharper decline in the earlier part of the period? There are two reasons. First, competitive pressure is weaker in the earlier part of the period, and hence the gap in productivity growth between the two regions is largest then. This leads to a relatively large increase in the relative price of the Rust Belt goods, and households substituting into the cheaper goods of the Sun Belt. Second, higher competitive pressure in the later period leads to a sharp drop in the markup of Rust Belt producers, and hence a sharp drop in the relative price of their goods. In the model this leads to the spike in the Rust Belt's employment share in 1985. In reality, presumably, the increase in competition did not hit all Rust Belt industries exactly at the same time. Thus, the more favorable prices of Rust Belt goods resulting from competition might have played out more smoothly over time in reality than in the model.

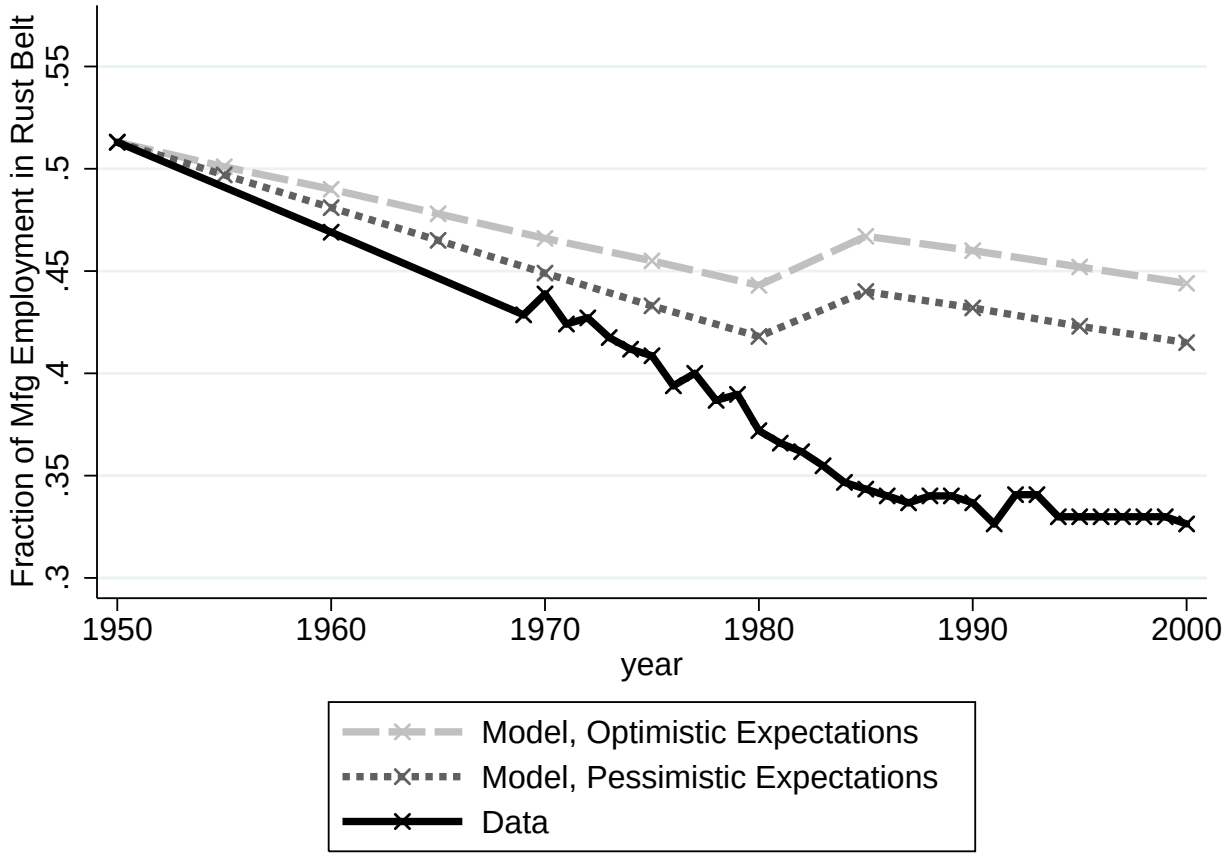

Figure 3: Fraction of Manufacturing Employment in Rust Belt: Model and Data

A second question is why the the Rust Belt's decline is less drastic in the optimistic-expectations scenario than the pessimistic-expectations scenario. The reason has to do with the relative strengths of the escape-competition effect and the Schumpeterian effect of output-market competition. In the optimistic-expectations scenario, the Rust Belt firms expect to have very weak competition from the fringe for a long time. This encourages them, all else equal, to do more investment than they otherwise would, since they can reap the benefits of their investments for a long period. In the pessimistic-expectations scenario, on the other hand, firms expect just a short stint with a weak fringe before the game is up, as it were. Thus, firms invest less than they otherwise would, and hence the Schumpeterian effect is relatively weak in this case.

6.3. Investment and Productivity Growth

What do the model's predictions for investment and relatively productivity growth look like? The model predicts that investment expenditures average 3.3 percent of value added in the Rust Belt, compared to 6.5 percent in the Sun Belt. Thus, investment rates are substantially lower in the Rust

Belt than in the remainder of the economy.

As a result, productivity growth rates are substantially lower in the Rust Belt. The model's average annualized productivity growth rate (in the pessimistic state) for Rust Belt producers is 1.4 percent; in the Sun Belt this figure is 2.3 percent. Worth noting is that predicted productivity growth is lowest in the early period in the Rust Belt, at 1.3 percent per year from 1950 to 1980, and rises to 1.6 percent per year after 1980. In the Sun Belt, productivity growth is 2.4 percent per year before 1980 and falls slightly to 2.1 percent afterwards. Thus, the difference in productivity growth rates converged somewhat over the period. After 2000, in the competitive state, the model predicts that productivity growth rates are both exactly two percent per year (as per the calibration.)

7. Supporting Evidence on Investment and Productivity Growth

In this section we present additional evidence on the model's predictions for investment and productivity growth. In particular, we consider evidence on R&D expenditures, TFP growth, and technology adoption rates. While each has its limitations, taken together they support the model's prediction that investment and productivity growth were relatively low in Rust Belt industries for most of the post-war period.

7.1. R&D Expenditures

The first piece of evidence we consider is on R&D expenditures by industry. Expenditures on R&D provides a nice example of costly investments that are taken to improve productivity, as in the model.

Evidence from the 1970s suggests that R&D expenditures were lower in key Rust Belt industries, in particular steel, automobile and rubber manufacturing, than in other manufacturing industries. According to a study by the U.S. Office of Technology Assessment (1980), the average manufacturing industry had R&D expenditures totaling 2.5 percent of total sales in the 1970s. The highest rates were in communications equipment, aircraft and parts, and office and computing equipment, with R&D representing 15.2 percent, 12.4 percent and 11.6 percent of total sales, respectively. Auto manufacturing, rubber and plastics manufacturing, and "ferrous metals," which includes steelmaking, had R&D expenditures of just 2.1 percent, 1.2 percent and 0.4 percent of total sales. These data are qualitatively consistent with the model's prediction that investment rates were lower in the Rust Belt than elsewhere in the United States.[20]

[20]Several sources explicitly link the lack of innovation back to a lack of competition. For example, about the U.S. steel producers Adams and Brock (1995) state that "their virtually unchallenged control over a continent-sized market made them lethargic bureaucracies oblivious to technological change and innovation. Their insulation from competition induced the development of a cost-plus mentality, which tolerated a constant escalation of prices and

Table 4: TFP Productivity Growth by Individual Rust Belt Industries

	Annualized Growth Rate, %		
	1958-1980	1980-2000	1958-2000
Iron and Steel Foundries	0.0	0.5	0.2
Machinery, Misc	−0.4	−0.1	−0.2
Motor Vehicles	1.0	0.2	0.6
Railroad Equipment	1.0	−0.3	0.3
Rubber Products	−0.2	2.5	1.1
Steel Mills	0.4	0.9	0.7
Rust Belt Average	0.3	0.6	0.4
U.S. Economy	2.0	1.4	1.8

Note: Rust Belt Industries are defined as those industries whose employment shares in Rust Belt MSAs are more than one standard deviation higher than the mean in both 1950 and 2000. Source: Author's calculations using NBER CES productivity database, U.S. census data from IPUMS, and the BLS.

7.2. Productivity Growth

Direct measures of productivity growth by region do not exist unfortunately. Nevertheless, we can assess the model's predictions for productivity growth in the Rust Belt by comparing estimates of productivity growth in industries that were prominent in the Rust Belt region over the period 1950 to 2000 to productivity growth in the rest of the economy.

Concrete estimates of productivity growth by industry are available from the NBER CES database.[21] By matching their industries (by SIC codes) to those available to us in our IPUMS census data (by census industry codes), we are able to compute the fraction of all employment in each industry that is located in the Rust Belt in each year. We define "Rust Belt industries" as all those industries with employment shares in the Rust Belt greater than one standard deviation above the mean in both 1950 and 2000. The industries that make the cut are Iron and Steel Foundries, Miscellaneous Machinery, Motor Vehicles, Railroad Equipment, Rubber Products, and Steel Mills.

Table 4 provides estimates of total-factor productivity (TFP) growth per year in these industries over several time horizons. As a frame of reference, we compute TFP for the U.S. economy as a whole as the Solow Residual from a Cobb-Douglas production function with labor share two-thirds and aggregate data from the BEA. The right-most column shows the entire period of data

wages and a neglect of production efficiency (page 93). "

[21] A detailed description of the data, and the data themselves, are available here: http://www.nber.org/nberces/.

availability, namely 1958-2000. TFP growth was lower in every Rust Belt industry than for the U.S. economy as a whole. The highest growth was in Rubber Products, which grew at 1.1 percent per year, while the lowest was in Machinery, which grew at -0.2 percent per year. The U.S. economy, on the other hand, had far higher TFP growth of 1.8 percent per year over this period.

The first and second two columns show TFP growth by industry in the periods 1958-1980 and 1980 to 2000. We choose this breakdown based on the evidence of Section 3 that competition picked up in the 1980s. The first two columns show that in four of the six industries – Iron and Steel Foundries, Machinery, Rubber Products, and Steel Mills – productivity increased in the period after 1980. This is consistent with the productivity pickup found in the model in the latter part of the period.

One limitation of these data is that what we define as Rust Belt industries include a lot of economic activity that does not take place in the Rust Belt. This is particularly true in the later period of the sample, when the Rust Belt's share of activity had fallen substantially. For the auto industry, we address this concern (at least in part) by computing the rate of growth of automobiles produced per worker for the Big Three auto makers, who had the majority of their auto production in the Rust Belt region, using company annual reports. We find that GM, Ford and Chrysler had average annual productivity growth rates of 1.1 percent, 1.3 percent and 1.8 percent respectively.[22] As these growth rates are all lower than the economy-wide average of around 2 percent per year, they suggest that Rust Belt automobile productivity growth was indeed lower than average.

For the steel industry, Collard-Wexler and De Loecker (2012) (Table 10) report 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 the period 1963 to 1982, and in fact negative for much of the period. From 1982 to 2002 they report very robust TFP growth in the vertically integrated mills, totaling 11 percent 1982 and 1987, and 16 percent between 1992 to 1997. This supports the claim that Rust Belt steel productivity growth was relatively low over the period before the 1980s, and picked up only afterwards.

A second limitation of the productivity evidence of Table 4 is that it compares Rust Belt industries to other industries that may have differed in "potential productivity growth." In other words, it compares newer industries, such as computers, where there is a large scope for productivity growth, than in more-established industries, such as steel and autos. To address this limitation, we compare productivity growth in the U.S. steel and auto industries to foreign steel and auto industries. The

[22] The company reports are all publicly available from the companies themselves. The exact years used differ slightly across the three companies due to data availability. The data for GM, Ford and Chrysler begin in 1954, 1955 and 1950, respectively.

idea is that comparing the key Rust Belt industries to similar industries abroad, one can see how the Rust Belt fared compared to other producers with similar scope for productivity growth.

For the auto industry, Fuss and Waverman (1991) compare the performance of the United States industry to that of Japan. They calculate that between 1970 and 1980, TFP growth in the Japanese auto manufacturing industry averaged 4.3 percent per year. In the U.S. auto industry, in contrast, TFP growth averaged just 1.6 percent.[23] For the steel industry, Lieberman and Johnson (1999) (Figure 8) compute that TFP in the U.S. vertically integrated mills was roughly constant from 1950 to 1980. Over the same period, TFP in the Japanese steel industry roughly *doubled*. Thus, in both the auto and steel industry, evidence suggests that the Rust Belt producers experienced productivity growth substantially below that of the foreign producers in their same industries.

7.3. Technology Adoption

Another proxy for productivity-enhancing investment activity is the rate of adoption of key productivity-enhancing technologies. 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 (Adams and Brock, 1995; Adams and Dirlam, 1966; Lynn, 1981; Oster, 1982; Tiffany, 1988; Warren, 2001). 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. Figure 7 shows adoption rates of continuous casting methods in the United States, Japan and several other leaders in steel production. Two things are worth noting from this figure. First, the United States was a laggard, with only 15 percent of its capacity produced using continuous casting methods, compared to a high of 51 percent in Japan, by 1978. Second, this was the period where large integrated steel mills of the Rust Belt dominated production. Putting these two observations together implies that the Rust Belt lagged far behind in the adoption of one important technology over the period.[24]

There is also agreement that the U.S. steel industry had ample opportunities to adopt the new technologies and chose not to do so. For example Lynn (1981) states that "the Americans appear to have had more opportunities to adopt the BOF than the Japanese when the technology was relatively new. The U.S. steelmakers, however, did not exploit their opportunities as frequently as the Japanese." Regarding the potential for the U.S. Steel Corporation to adopt the BOF, Warren

[23] Norsworthy and Malmquist (1983) find slightly lower numbers for an earlier period, but still find lower TFP growth for the U.S. auto industry than for the Japanese auto industry.

[24] In the 1980s and afterward, the U.S. steel industry made large investments in a new technology, the minimill, which used an electric arc furnace to turn used steel products into raw steel for re-use. Virtually all of these adoptions were made outside of the Rust Belt region, and in the U.S. South in particular. See Collard-Wexler and De Loecker (2012) and the references therein.

(2001) describes the 1950s and 1960s as "a period of unique but lost opportunity for American producers to get established early in the new technology."[25]

The view that technology adoption in the U.S. steel industry was inefficiently low is in fact confirmed by the producers themselves. In their 1980 annual report, the American Iron and Steel Institute (representing the vertically integrated U.S. producers) admit that:

> Inadequate capital formation in any industry produces meager gains in productivity, upward pressure on prices, sluggish job creation, and faltering economic growth. These effects have been magnified in the steel industry. Inadequate capital formation ... has prevented adequate replacement and modernization of steelmaking facilities, thus hobbling the industry's productivity and efficiency (American Iron and Steel Institute, 1980).

Similar evidence can be found for the rubber and automobile manufacturing industries. In rubber manufacturing, Rajan, Volpin, and Zingales (2000) and French (1991) argue that U.S. tire manufacturers missed out on the single most important innovation of the postwar period, which was the radial tire, adopting only when it was too late (in the mid 1980s). The big innovator of the radial tire was (the French firm) Michelin (in the 1950s and 1960s). According to French (1991), most of the U.S. rubber tire producers hadn't adopted radials even by the 1970s, even as Michelin drastically increased its U.S. market share.

The sluggish rate of technology adoption by the auto industry seems to be widely acknowledged by industry historians and insiders, such as Adams and Brock (1995), Ingrassia (2011) and Vlasic (2011). As one example, Halberstam (1986) writes

> Since competition within the the [automobile manufacturing] industry was mild, there was no incentive to innovate; to the finance people, innovation not only was expensive but seemed unnecessary... From 1949, when the automatic transmission was introduced, to the late seventies, the cars remained remarkably the same. What innovation there was came almost reluctantly (p. 244).

To summarize the results of this section, investment and productivity growth seemed to be lower among Rust Belt industries than other U.S. industries, and lower than they could have been given

[25] As just one example, Ankl and Sommer (1996) report an engineer at the U.S. Steel Company visited the Austrian Linz BOF plant in 1954 and brought back a favorable report on the prospects of the BOF. Management at U.S. Steel vetoed this line of research and reprimanded the engineer for making an unauthorized visit to the Austrian firm (pp 161-162.)

available investment opportunities, particularly before the 1980s. This supports the model's predictions that Rust Belt investment and productivity growth rates were low, and particularly so before the 1980s when competition was at its lowest.

8. Supporting Evidence from Cross-Section of Metropolitan Areas

In this section we provide some additional evidence that supports the role of limited competition in the Rust Belt's decline. Specifically, we look beneath the surface of the regional aggregates focused on until now, and consider the cross-section of Metropolitan Statistical Areas (MSAs) within the United States. What we show is that MSAs that had the lowest employment growth over the period 1950 to 2000 tended to be those that paid workers the highest wage premiums in 1950. Our results in this section corroborate the earlier results of Borjas and Ramey (2000), who document that *industries* paying the highest wage premiums in 1959 had the lowest employment growth through 1989. As many of the high-wage industries in their study (e.g. autos and steel) were concentrated in the high-wage MSAs of our study (e.g Detroit and Pittsburgh), we conclude that both sets of evidence are consistent with the basic prediction of the model.

The data we use for this analysis is the decennial census micro data available from IPUMS. The unit of geography is, as mentioned above, the MSA, which corresponds roughly to a city plus its surrounding suburbs. We report MSA-level statistics for all MSAs in the country that are above a certain size threshold (determined by the Census Bureau), usually around 100,000 people. The place of residence is excluded for confidentiality reasons in smaller MSAs or rural areas. We also focus attention to 3-digit MSAs as defined by IPUMS, as these have changed definition relatively infrequently over time (unlike the 4-digit MSAs.)

We consider all workers who report being primarily wage earners, as opposed to the self-employed, and only those employed in the private sector. The reason for these restrictions are to limit possible biases in our measurement of wage premiums, as well as to keep our sample as standard as possible. We note that our results carry over to alternative sample restrictions, such as only men, only full-time workers, only household heads, and combinations thereof.

We construct our measures of wage premiums as follows. As in many standard macroeconomic models, we assume that under competition, the workers' wage should be proportional to their human capital. Following the tradition of Mincer, we assume that a worker's human capital is a function their schooling and potential work experience. We build on these assumptions by letting a worker's wage depend on where they live, with some regions offering a larger payment per unit of human capital than others. In particular, we assume that the log hourly wage of worker i in region

m is

$$\log w_{i,m} = \alpha \cdot SCHOOL_{i,m} + \sum_{j=1}^{4} \beta_j \cdot EXPER_{i,m}^{j} + \sum_{m=1}^{M} D_m \cdot \pi_m + \varepsilon_{i,m} \tag{23}$$

where $SCHOOL_{i,m}$ and $EXPER_{i,m}$ represent years of schooling and potential experience, D_m is a dummy for residing in region m, and $\varepsilon_{i,m}$ is an error term. The coefficients α and β_1 through β_4 capture the returns to schooling and experience while the π_m terms capture the "premium" that a worker earns for living in region m controlling for schooling and experience.

We estimate (23) using the IPUMS micro data (from 1950), and take the π_m terms as our measure of wage premiums by MSA. We emphasize that these measures are best thought of as suggestive due to the crude way in which they are calculated. One limitation for example is that other potentially important MSA-level characteristics are omitted from the regression, such as cost-of-living indices. Another limitation is that schooling and potential experience themselves are imperfect proxies for human capital. Nevertheless, we argue that these wage premium measures are still useful in describing and understanding regional differences in economic performance over the post-war period.

Figure 4 shows the wage premium in 1950 (normalized to 0) plotted against the annualized growth in employment from 1950 to 2000. Rust Belt MSAs are displayed in black, while the rest are grey. As can be seen in the figure, there is a negative correlation between the two variables, with regions with the highest premiums in 1950 tending to have the worst subsequent employment growth. The correlation coefficient is -0.44, and is significant at well below the 1-percent level.

Which are the regions on either end of the spectrum? Among the MSAs with high wage premiums are South Bend, IN (SOB), Detroit, MI (DET), Jackson, MI (JCS), Chicago-Gary-Lake, IL (CHI), Pittsburgh, PA (PIT), Youngstown-Warren, OH (WAR), and Flint, MI (FLI). Each of these MSAs was home in 1950 to a major manufacturing center in the automobile or steel industries.[26] Among those with low wage premiums are Orlando, FL (ORL), Austin, TX (AUS), Phoenix, AZ (PHX), Raleigh-Durham, NC (RAL) and Greensboro-Winston Salem-High Point, NC (GRB). These MSAs have all been referred to as being part of the "Sun Belt" (by Blanchard and Katz (1992), among others).

One potential alternative theory of the wage premiums in the Rust Belt is that workers there tended to be of higher-than-average ability. This could be the case, say, if talented workers in the 1950s tended to be attracted disproportionately to the Rust Belt regions because labor markets there were strong at the time. According to this theory, the interpretation of the above-average wages as

[26] See e.g. Vlasic (2011) or Ingrassia (2011) on auto manufacturing, and Tiffany (1988) or Crandall (1981) on steel. South Bend, Detroit, Jackson and Flint were major auto producers; Pittsburgh, Youngstown-Warren and Chicago-Gary-Lake were steelmaking centers.

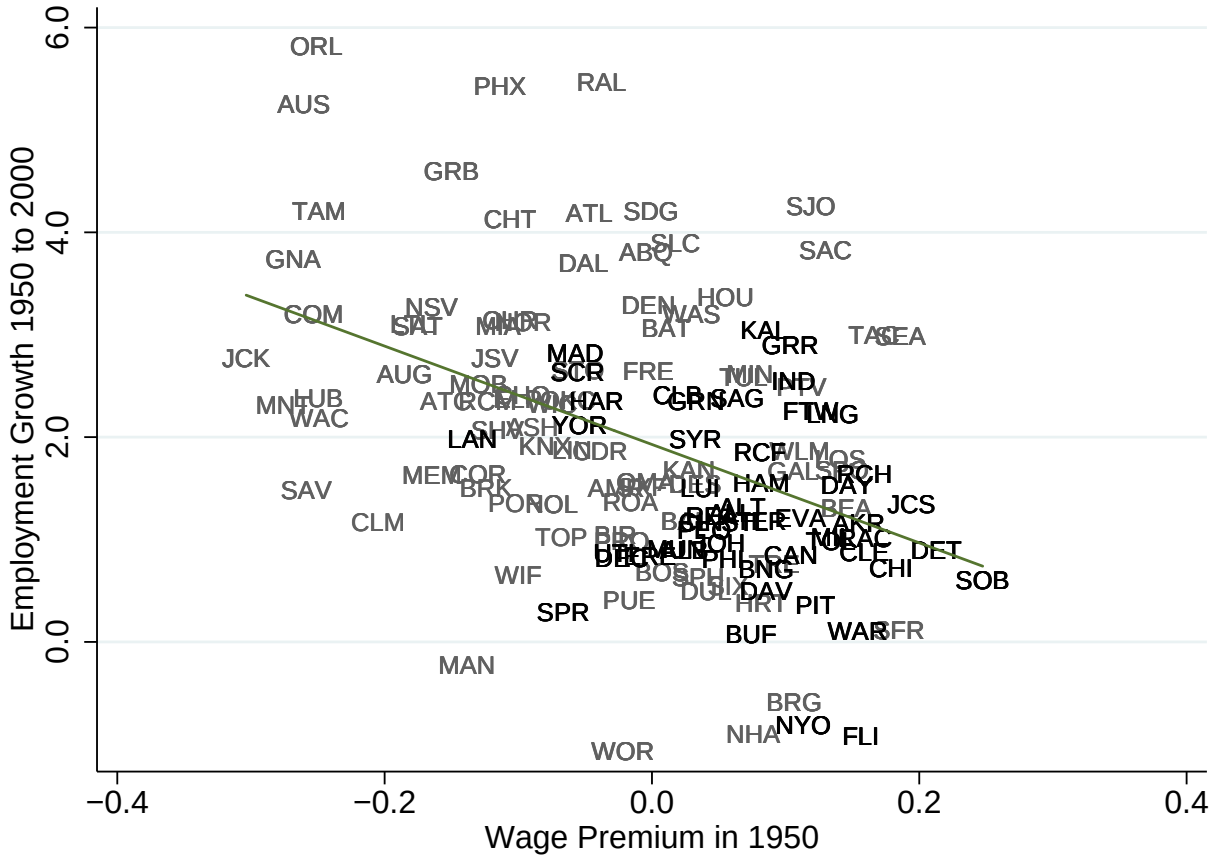

Figure 4: Wage Premiums and Employment Growth across MSAs

premiums is erroneous, and instead the higher than average wages earned by workers in this region simply reflected their higher productivity.

One piece of evidence against this hypothesis is that workers in industries common in the Rust Belt tended to suffer some of the largest wage losses in percent terms after a (plausibly) exogenous displacement, compared to workers in other industries (Carrington and Zaman, 1994; Jacobson, Lalonde, and Sullivan, 1993). Carrington and Zaman (1994) find that displaced workers in the typical industry lost about 10 percent of their pre-displacement wage when moving to a new job. In contrast, workers in the "primary metal manufacturing" industry lost around 26 percent of their wages, and workers in "transport equipment manufacturing" and "rubber and plastics manufacturing" lost around 20 percent. This evidence is more consistent with the hypothesis that these workers were earning wage premiums than with the hypothesis that these workers were disproportionately the most productive workers.

9. Conclusion

While the U.S. economy as a whole experienced robust economic growth over the postwar period, there was substantial variation in the economic performance of regions within the country. No region fared worse than the Rust Belt, the heavy manufacturing zone bordering the Great Lakes. The Rust Belt's share of employment and value added fell drastically over this period, both overall and within the manufacturing sector.

Our theory is that a lack of competition was behind the Rust Belt's poor economic performance. We formalize our theory in a dynamic general equilibrium model in which productivity growth is driven by the strength of competition in labor and output markets. Non-competitive labor markets lead to a hold-up problem between workers and firms, which discourage firms from investing. Non-competitive output markets reduce the firm's incentive to invest in order to escape the competition. A plausibly calibrated version of the model predicts roughly one-half of the decline found in the data. The model also predicts that the Rust Belt lagged behind in investment in new technologies and productivity growth. These predictions are borne out in several types of evidence from prominent Rust Belt industries.

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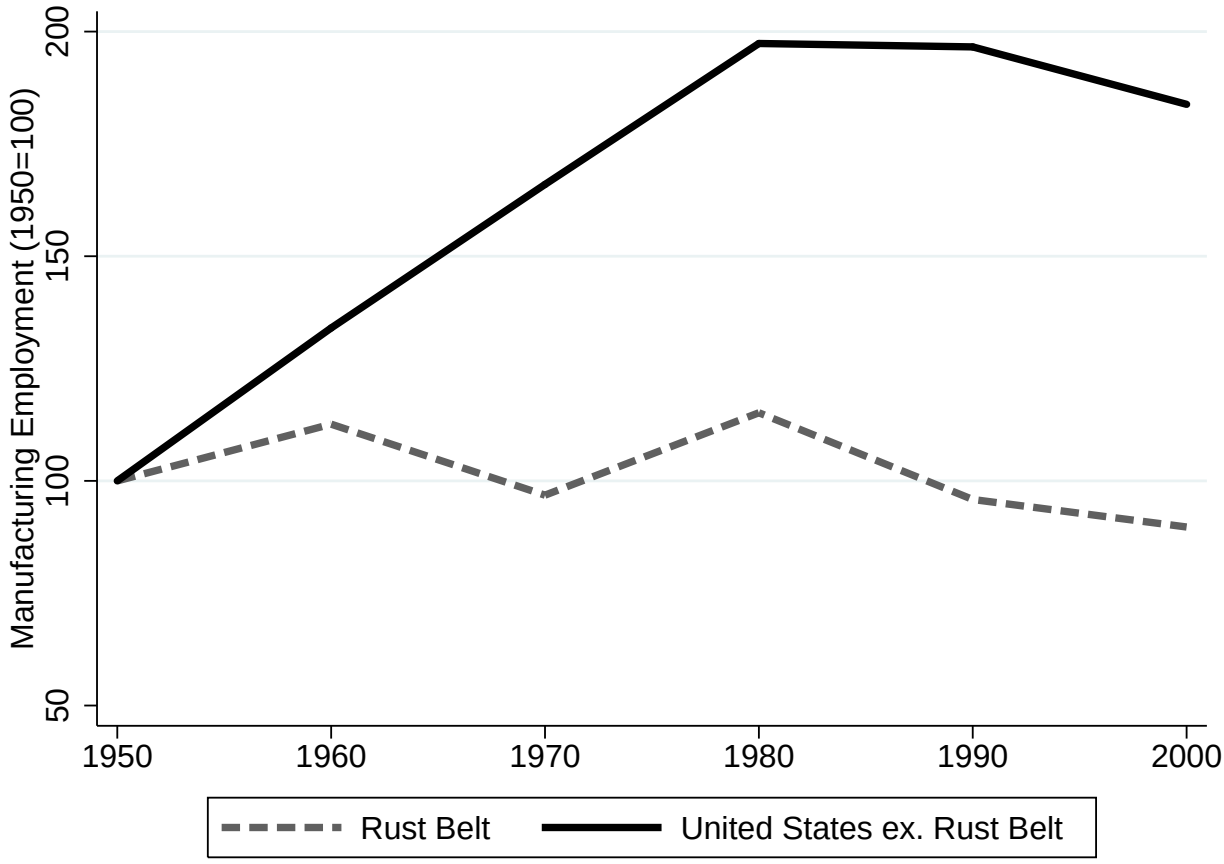

Figure 5: Manufacturing Employment in Rust Belt and Rest of United States

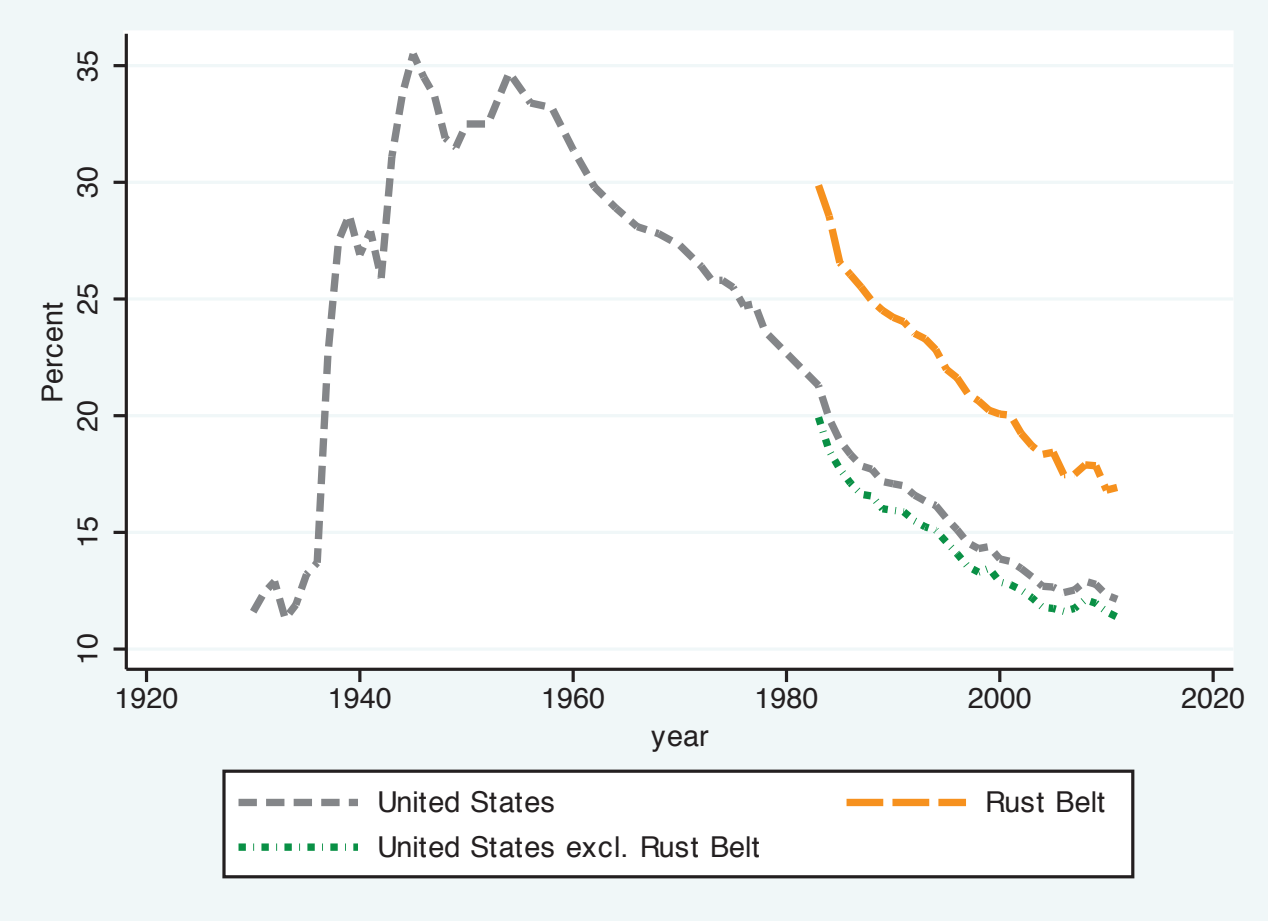

Figure 6: Unionization Rate in the United States and by Region

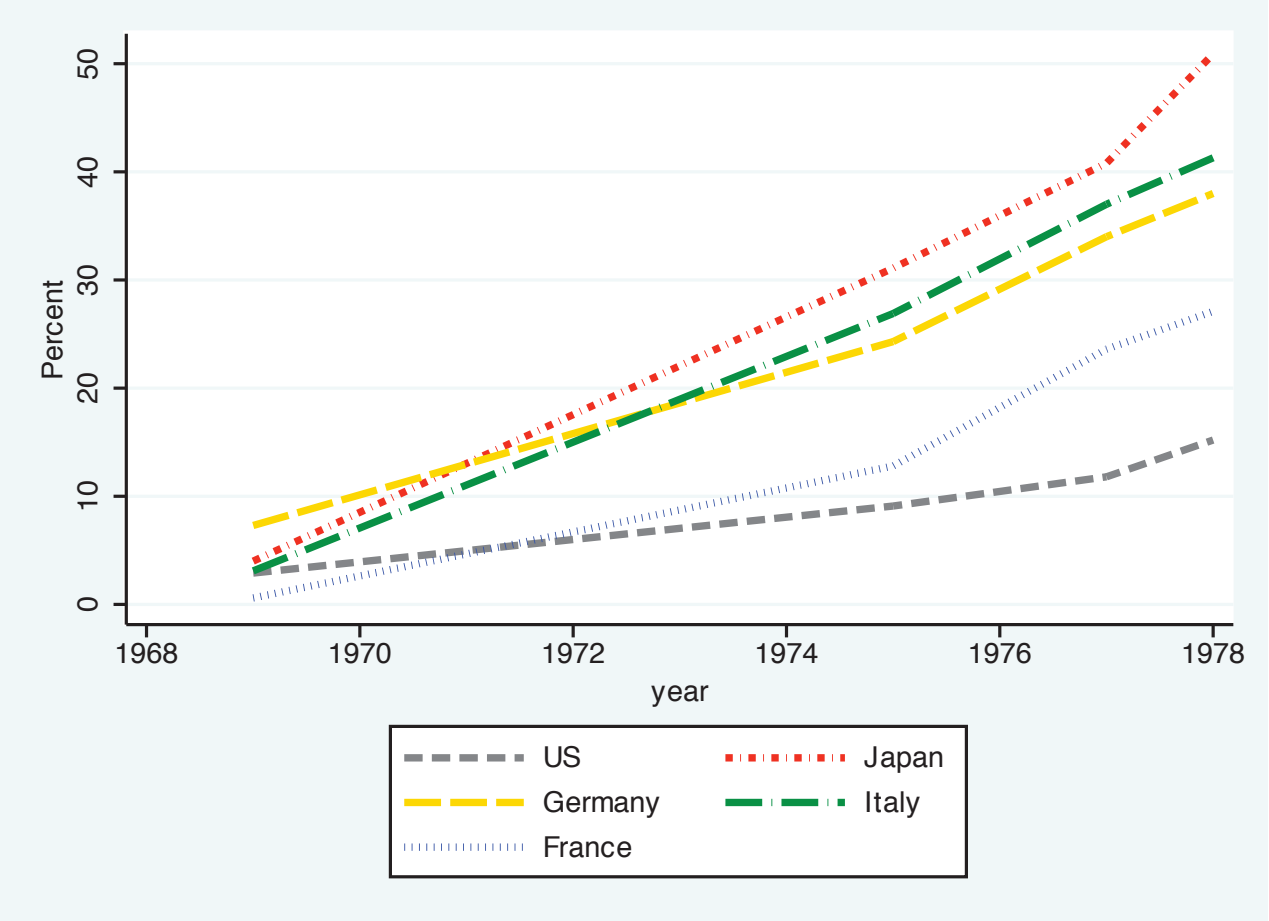

Figure 7: Fraction of Steel Made Using Continuous Casting Process