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Competitive Pressure and Labor Productivity: World Iron Ore Markets in the 1980s

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Abstract

Does the extent of competitive pressure industries face influence their productivity? We study a natural experiment conducted in the iron ore industry as a result of the collapse in world steel production in the early 1980s. For iron ore producers, whose only market is the steel industry, this collapse was an exogenous shock. The drop in steel production differed dramatically by region: it fell by about a third in the Atlantic Basin but only very little in the Pacific Basin. Given that the cost of transporting iron ore is very high relative to its mine value, Atlantic iron ore producers faced a much greater increase in competitive pressure than did Pacific iron ore producers. In response to the crisis, most Atlantic iron ore producers doubled their labor productivity; Pacific iron ore producers experienced few productivity gains. This article originally appeared in the *American Economic Review*. © American Economic Association.

Does the extent of competitive pressure industries face influence their productivity? While a widespread view says that competitive pressure does influence productivity, and some theoretical reasons to expect gains exist, the amount of evidence to support this view is not overwhelming.[1] Evidence has been sought, for example, in the impact of economic liberalization policies, such as deregulation, privatization, and tariff reductions, on productivity. These policies are thought to increase competitive pressure on industries and, hence, to lead to productivity gains.[2] But the evidence that they increase productivity is not overpowering. This lack of evidence may well stem from issues such as policy endogeneity. Here we study a situation akin to a natural experiment in which competitive pressure was brought upon producers by a shrinking market for their product. In particular, we examine the increased competitive pressure iron ore producers faced in the early 1980s following the collapse of world steel production.

We show that a striking relationship exists between the increase in competitive pressure iron ore mines faced in the early 1980s and their subsequent labor productivity gains in the 1980s. In countries where mines faced little increase in competitive pressure, productivity changed little over the 1980s; in countries where mines faced dramatic increases, productivity gains ranged from 50 to 100 percent, rates that were unprecedented.

We say that the collapse of world steel production led to an *increase in competitive pressure* at a mine if because of the collapse the likelihood that the mine would close over, say, the next decade, increased. The increase in competitive pressure a mine faced depended on a number of factors, but two were paramount: the mine's location and the mine's production costs.

Location was paramount because the costs of shipping iron ore are high relative to the ore's value at the mine. (Transport costs often amount to 50 percent and more of delivered prices.) The steel production collapse in the early 1980s was almost entirely concentrated in the Atlantic Basin. Because iron ore mines in Atlantic Basin countries (Brazil, Canada, France, South Africa, Sweden, and the United States) were located in the region of the steel collapse, they faced, everything else equal, a greater increase in competitive pressure than mines in Pacific Basin countries (Australia and India).[3]

Production costs were, obviously, also paramount in determining the increase in competitive pressure a mine faced. The production costs of mines in Atlantic Basin countries (with one exception) greatly exceeded the production costs of mines in Pacific Basin countries. Hence, on both counts, the Atlantic Basin mines faced a greater increase in competitive pressure than the Pacific Basin mines.

Regarding production costs, the exception was Brazil: its mines had the lowest production costs in the world. As we demonstrate below, the Brazilian mines were like those in the Pacific Basin countries in that they faced little increase in competitive pressure.

Among those mines that faced little or no increase in competitive pressure, Australian and Brazilian mines had no productivity gains in the 1980s (and few in the preceding decade either); Indian mines had modest productivity gains, about 29 percent in the 1980s (55 percent in the preceding decade). Among mines that faced a dramatic increase in competitive pressure, Canadian, Swedish, and U.S. mines had productivity gains approaching 100 percent in the 1980s (whereas each had no productivity gain in the preceding decade); South African mines had substantial gains, about 50 percent in the 1980s; and French mines had no productivity gains and by the end of the 1980s were (essentially) out of the business. France demonstrates that not all industries that face a dramatic increase in competitive pressure will increase productivity. (See discussion below.)

As we mentioned, evidence for the influence of competitive pressure on productivity is often sought in economic liberalization episodes. But studying these experiences presents a number of difficulties. First, a change in policy may not increase competition. For example, some government-owned businesses are subject to the same competitive pressure as their private counterparts; hence, privatization need not increase competitive pressure. (See, for example, Caves and Christensen 1980.) Second, there is the issue of policy endogeneity. Privatization choices and tariff choices are made in the political forum. It's often hard, then, to argue that tariff reductions are akin to exogenous shocks (or random treatments). Perhaps industries that are expected to have significant productivity declines are the ones that lose political support and suffer the greatest tariff reductions. In that case, reductions in tariffs might be correlated with productivity declines. Third, measuring productivity is often difficult. (See Megginson and Netter 2001, for example, pp. 332, 346.) Perhaps because of these and other difficulties, there is not overwhelmingly support that liberalization policies lead to significant productivity gains.[4]

In the situation we study, these difficulties are very much lessened. First, the collapse of world steel production clearly increased the competitive pressure on many iron ore mines. Second, we argue below that the increase in competitive pressure a mine faced was like an exogenous shock. Third, given the simple nature of the product in the industry, calculating productivity is relatively simple.

Experience with economic liberalization policies is, of course, not the only source of information on competitive pressure. For example, a notable study by Nickell (1996), whose measures of competition include a survey-based measure (with firms asked whether they have five or more competitors) and a measure of rents (with lower rents signaling greater competition), shows that firms facing greater competition had greater productivity growth. Zitzewitz (2003) argues that periods of increased competition in the tobacco industry (measured by changes in the number of firms) led to productivity gains. Borenstein and Farrell (1999) look at changes in the price of a firm's product. They show that when the price of gold increases, the stock market value of gold mining companies does not increase as much when gold's price was initially high rather than low. They take this as evidence that waste and inefficiency increase as corporate wealth grows (and, in our language, as competitive pressure falls). (See also the work of Baily (1993) and Baily and Gersbach (1995).)

What were the sources of productivity gains in the Atlantic Basin mines triggered by increases in competitive pressure in the 1980s? Industry analysts attribute most of the gains in the U.S. and Canadian iron ore industries to changes in work rules (Kakela, Kirsis, and Marcus 1987).[5] Here we argue that the closing of low productivity mines (in the United States), shifts in the types of iron ore produced, and the introduction of new technology were not important sources of gains. Productivity gains, then, were primarily driven by continuing mines, producing the same products and using existing technology. While this is consistent with the work rule story, to show that work rule changes were the driving factor requires work beyond our scope here. (But see Schmitz 2001.)

In the next section, we provide a brief background on the iron ore industry and the world steel collapse in the early 1980s. In the following section, we define what we mean by an *increase in competitive pressure* and then classify mines according to the increase in competitive pressure they faced in the early 1980s. In the next section, we present the production and productivity records of the top iron ore producing countries and briefly discuss the sources of the productivity gains.

Background

Iron ore is used, almost exclusively, as an input to steel production. Moreover, the costs of iron ore make up a small fraction of the value of steel, typically about 10 percent. Hence, as the steel market goes, so goes the iron ore market.

The eight noncommunist countries that produced the most iron ore in 1980 are listed in Table 1.[6] The table lists each country's iron ore production in 1980 as reported by both the U.S. Geological Survey (USGS) and each country itself.[7] The two production reports are nearly identical. Total USGS production in 1980 for these eight countries was about 81 percent of total noncommunist production.[8] The table also lists the percentage of iron in the iron ore of each country reported by the USGS.

Transport costs in the iron ore industry are typically a large share of delivered prices. Moreover, transport charges depend in an important way on the length of trip, so that transporting out of a local area adds significantly to transport charges.[9] These features can be seen in Table 2, which shows rail transport costs and ocean freight costs for selected iron ore mines in 1994.[10] The table shows the average rates per ton for rail transport of iron ore from mines to port of export, the average charges for ocean transport from port of export to various markets around the world, and delivered prices for two types of iron ore, concentrates and pellets.[11]

To see that transport charges were a large share of delivered prices, consider the Brazilian producer Samitri. It paid $14.00 a ton to transport concentrate to Europe [$7.50 (rail) + $6.50 (ocean)]; this equaled 51 percent of the delivered price. To see that length of trip was important, consider the ocean charges on Australian iron ore. The average charge per ton to Baltimore was more than twice the charge per ton to Japan ($11.55 versus $5.50). The average charge per ton to Northern Europe was nearly 65 percent greater than the charge per ton to Japan ($9.05 versus $5.50).[12]

When iron ore is used to make steel, it is first turned into a crude form called *pig iron.* Hence, a direct measure of the use of iron ore by steel producers is the production of pig iron. In Chart 1, we plot the world production of steel and pig iron between 1950 and 1996, as reported by the U.S. Geological Survey. The collapse of world steel production in the early 1980s is evident. From 1979 to 1982, steel production dropped 20 percent. Production did not return to its precollapse, or precrisis, level until 1993. Pig iron fared worse. By 1996, steel production was about 10 percent higher than its precrisis level, but pig iron production had barely climbed above its precrisis level. Pig iron production fared worse, of course, because steel producers that used virgin iron ore (integrated steel producers) fared worse than steel producers that primarily used scrap (minimills).

Steel production also dropped significantly beginning in 1974. However, most steel industry observers thought the 1974 drop would be short-lived and that world steel production would return to its trend growth.[13] But the drop in the early 1980s was different: it became clear that some mines would need to be closed.

Competitive Pressure . . .

In this section, we define what we mean by an *increase in competitive pressure*. We then classify the extent of the increase in competitive pressure iron ore mines faced following the collapse of world steel production.

Definition

Following the collapse of world steel production in the early 1980s, the general view as to the probability of the possible paths of steel production changed significantly. (By the term *path,* we mean how much, and where, steel is produced.) Prospects for steel production in some areas were now much bleaker than those in other areas.

For each mine, following the collapse, we could ask, under the assumption that the mine's production costs and those of its competitors throughout the world did not change, what were the mine's chances of being closed over, say, the next decade?[14] By *increase in competitive pressure,* we mean the increase in the mine's probability of closure resulting from the steel collapse. If the steel production in a mine's local area faced much dimmer prospects after the steel collapse, and if the mine's production costs were high relative to other mines across the world, then the mine obviously faced a significant increase in competitive pressure.[15]

Production Collapse and Costs

□ *Location*

The drop in steel and pig iron production between 1979 and 1982 was concentrated in the Atlantic Basin. In Chart 2, we plot pig iron production in the Atlantic and Pacific Basin countries over 1950–96. Pig iron production in the Atlantic Basin fell nearly 75 million metric tons between 1979 and 1982, essentially the entire world drop in production. Moreover, Atlantic Basin production in 1996 was still significantly off its 1979 level. In contrast, Pacific Basin production fell little between 1979 and 1982, and by the middle 1990s, production was well above its 1979 level.

Chart 3 shows pig iron production for various other groups of countries. Between 1979 and 1982, the sum of Canadian and U.S. production fell by about 50 percent; in France, the United Kingdom, and West Germany, production fell by about 20 percent; and in Japan, South Korea, and Taiwan, production fell very little.

□ *Cost Estimates*

A major effort to estimate mine production costs in the early 1980s was made by the U.S. Bureau of Mines (USBM) and reported in Bolis and Bekkala 1987. USBM-estimated production, or operating, costs at mines are given in Table 3.[16] Costs were estimated at a number of mines in each country (or region). The table also shows the number of mines studied in each country. The costs are broken down into the costs of mining the iron ore and the costs of beneficiation.[17] The USBM report presents only the range of costs in each country during 1984.

The top of Table 3 shows data for Atlantic Basin mines. Canadian, European (which includes Norwegian, Spanish, and Swedish), and U.S. mines clearly had higher costs than Brazilian mines. The range of mining costs in Brazil ($0.70–$2.00 per ton) was everywhere below the range in Canada ($2.00–$2.50), Europe ($2.60–$7.20), and the United States ($2.00–$4.50). The Swedish mines were underground, so the high $7.20 mining cost in Europe clearly belonged to Sweden. The range of beneficiation costs in Brazil ($0.50–$1.70 per ton) was everywhere below the range in Canada ($3.00–$3.50) and the United States ($3.25–$5.00) and nearly so in Europe ($1.50–$4.50). Clearly, then, the Brazilian mines had a far lower sum of mining and beneficiation costs than the Canadian, Swedish, and U.S. mines.[18]

The bottom of Table 3 shows data for Pacific Basin mines. Production costs for mines in those countries were much lower than for those in the Atlantic Basin countries, with the exception of Brazil. Brazil was the world's lowest-cost producer. While the range of beneficiation costs in Brazil ($0.50–$1.70 per ton) was similar to that in Australia ($0.30–$1.60) and India ($0.50–$1.50), mining costs in Brazil ($0.70–$2.00) were somewhat lower than in Australia ($1.60–$2.60) and India ($1.00–$5.00).[19]

Another major effort to estimate production costs was undertaken by Natural Resources Canada in the middle 1990s (Boyd and Perron 1997). While this study was a decade later than the USBM study and had a somewhat different definition of operating costs, the ranking of countries by production cost is the same in the two studies. Table 4 shows the operating costs (mining plus beneficiation plus other charges) of mines in the production of concentrate in 1994. Again, Canada, South Africa, and Sweden had significantly higher costs than Australia, Brazil, and India. Brazil still had the lowest-cost mines.

Mine Classification

Given the location of the steel collapse and the mine production costs, we can classify mines by the increase in competitive pressure they faced.

Let us for the moment compare all mines except Brazilian ones. The Pacific Basin mines had better locations to deal with the steel collapse, and lower production costs, than the Atlantic Basin mines. Hence, the Pacific Basin mines faced little increase in competitive pressure compared to the non-Brazilian Atlantic Basin mines.

Let us now introduce Brazil. The Brazilian iron ore industry's location was not unambiguously better than the other Atlantic Basin mines: Brazil is closer to the Pacific Basin than most of the Atlantic mines, yet it is farther from the Atlantic Basin steel production centers in North America and Northern Europe. But, as we show, Brazil's production costs were so low compared to the other Atlantic mines that Brazil could produce and ship iron ore to most Atlantic Basin steel centers more cheaply than Atlantic Basin mines that were closer to those steel centers. Hence, most non-Brazilian Atlantic Basin mines would close before any Brazilian mines. The Brazilian mines faced little increase in competitive pressure.[20]

Consider first the Brazilian mines and the non-Brazilian Atlantic Basin mines as competitors in Europe. Using Table 3, consider the Brazilian and Canadian mines. The greatest possible production cost for a Brazilian mine was $3.70 ($2.00 + $1.70). The least possible production cost for a Canadian mine was $5.00 ($2.00 + $3.00). Brazilian mines had a production cost advantage of at least $1.30 over Canadian mines.

Table 3 also shows ocean freight costs in 1984 from the USBM study (Bolis and Bekkala 1987). Rates are shown for various sizes of ships. On bigger ships, Brazil's ocean freight rate was $1.50 per ton more than Canada's ($4.50 on a ship of size 155 thousand deadweight tons compared to $3.00 on a ship of size 160 thousand deadweight tons). This difference of $1.50 is just a bit bigger than the (minimum) Brazilian production cost advantage of $1.30. However, Brazilian ore likely traveled on much larger ships. Brazil shipped much more iron ore to Europe than did Canada, and Brazil had much larger port facilities than Canada. (See Bolis and Bekkala 1987, Table 3, p. 6.) Brazil's average ocean costs were likely much closer to the Canadian costs. (In fact, recall Table 2, which shows that the Brazilian and Canadian average ocean freight charges to Europe were similar.)

Now compare Brazilian and Swedish mines as competitors in Europe. Recall that Sweden had a mining cost of $7.20 per ton. The highest production cost (mining and beneficiation) for a Brazilian mine was $3.70, while the lowest cost for a Swedish mine was $8.70 ($7.20 + $1.50). Brazilian mines thus had a production cost advantage of at least $5.00 over the Swedish mines. This cost advantage was roughly Brazil's ocean freight costs to Europe.

The same conclusions are reached from Table 4. Brazil could produce and ship to Northern Europe in 1994 at less cost than Canada and Sweden.

Now consider the Brazilian and U.S. mines as competitors in Europe. Actually, U.S. iron ore producers had no chance of competing with Brazilian producers in the European market. U.S. producers not only had higher production costs, as indicated in Table 3; they also had much higher transportation costs. These very high transport costs reflected the fact that U.S. iron ore was produced in the Great Lakes region, and shipping up the St. Lawrence Seaway involved significant costs. (For details, see Schmitz 2001.)

Finally, consider the Brazilian and non-Brazilian Atlantic Basin mines as competitors in North America, particularly in the United States. Before the early 1980s crisis, Brazil had already dominated many U.S. iron ore markets, for example, the U.S. East Coast market. But before the crisis, Brazil had not yet entered a major U.S. market, the one in the Great Lakes region. This market was supplied by iron ore producers in the United States (their only market) and Canada. However, as Brazil's other markets were shrinking in the early 1980s, Brazil began to enter the Great Lakes market. Even though transportation charges into that region were very high, Brazil's production costs were so low that Brazilian producers could still undercut the prevailing delivered iron ore prices. (Again, for details, see Schmitz 2001.)

We have classified the increase in competitive pressure iron ore mines faced by looking at their locations and production costs. Two other pieces of evidence corroborate our classification. First, the producers we categorize as facing the greatest increase in competitive pressure when steel production collapsed are also the producers that initially faced the steepest reduction in output. (See below.) Second, following the steel collapse, Brazilian mines were beginning to ship to some markets, such as Chicago, for the first time. This is indeed evidence that the U.S. mines around Chicago were facing great competitive pressure.

Finally, as we mentioned, the increase in competitive pressure a mine faced was like an exogenous shock. The increase in competitive pressure faced by a mine was determined in large part by the fall of steel production in its area. The world steel production collapse in the early 1980s was driven in the main by the world recession caused by the second oil shock. That steel production remained depressed after the recession was driven by, among other things, the accelerated substitution of materials like plastic for steel, stimulated by increases in the price of gas for cars in the middle 1970s. And the reasons for the Pacific Basin's growing share of steel production included the strong U.S. dollar in the early 1980s and the rapid growth of many of the developing Asian economies.

Steel production was, of course, determined by choices of steel producers, not nature. In this sense, the situation is not a natural experiment and the increase in competitive pressure was not a random treatment. But it's hard to think that the choices which led to steel production falling overall, and to Pacific Basin production increasing its share of world production, were influenced much, if at all, by the iron ore industry. The forces driving steel production were too big for the iron ore industry to influence.[21]

. . . And Labor Productivity

We now examine the iron ore production and productivity records of these top producers. We show that there was a close connection between the increase in competitive pressure at a country's mines and the productivity gains in the country's iron ore industry.[22]

Charts 4–6 show the countries where mines faced little or no increase in competitive pressure. Charts 7–11 show the countries where mines faced a significant increase. In each graph, *production* is the weight of iron ore produced, and *productivity* is production divided by hours worked (for Sweden and the United States) or production divided by average employment over the year (for the rest). We use the production figures reported by the country's statistical agency if they are available and, if not, the USGS production figures. We can do this because, as we saw on Table 1, the two sources report similar production figures.

In the early 1980s, production fell little in Australia, Brazil, and India (Charts 4–6) compared to the five other producers (Charts 7–11). Clearly, the producers we classify as facing the greatest increase in competitive pressure are also those that were initially hit hardest by the steel collapse. By the end of the 1980s, production had returned to or exceeded precrisis levels in Australia, Brazil, India, and South Africa; it had returned to about 80 percent of its precrisis level in Canada, Sweden, and the United States; and it dropped throughout the decade in France.[23]

The differences in the productivity records of the two groups is striking. Australia and Brazil had no productivity gains over the 1980s (and none over the preceding decade either). India had a productivity gain of 29 percent over the 1980s, but that was certainly smaller than its gain of 55 percent over the 1970s. Canada, Sweden, and the United States all had gains that approached 100 percent over the 1980s, whereas each had essentially no productivity gains over the 1970s. South Africa had impressive productivity gains of 50 percent during the decade of the 1980s, while France had no gains.

Those countries that faced significant increases in competitive pressure had much greater productivity gains than those that faced little increase. The exception is France. But, as we mentioned above, there are reasons to expect that not all industries that are faced with an increase in competitive pressure will respond by increasing productivity.[24]

An Explanation?

In this section, we briefly argue that the productivity gains observed in Charts 4–11 were driven by continuing mines, producing the same products and using the same technology as they had before the 1980s. This is consistent with the change-in-work-rule explanation offered by industry analysts for the U.S. and Canadian gains.

Mine closings in the United States contributed little or nothing to the U.S. productivity gains. Using mine-level data, and conducting a standard industry productivity growth decomposition, Schmitz (2001) shows that the closing of mines contributed between 0 and 7 percent (depending on the years) to industry productivity gains.[25] We conjecture that mine closings contributed little in other countries either, although this must await future research.[26]

Changes in the type of product produced contributed nothing to the gains. Of the three major types of iron ore (lump, concentrates [or *fines*], and pellets), more labor is required to produce a ton of pellets than a ton of the other two. Chart 12 shows pellet production as a percentage of total iron ore production in 1970–90 in four countries.[27] Over the 1980s, there clearly was a shift toward pellets in Canada, Sweden, and the United States. Hence, the productivity gains in Charts 7, 10, and 11 during the 1980s were not due to a shift toward products that required less labor to produce. This shift toward products requiring more labor per ton indicates that the gains in producing each type of iron ore were greater than the aggregate productivity gains. In this sense, the productivity gains in the 1980s (in Charts 7, 10, and 11) for these three countries are understated.[28]

New technology also contributed little to the gains. The technology in this mature industry changes very slowly.[29] There have been gradual improvements in technology, of course, and these gradual improvements have led to much better iron ore products and higher productivity. Examples of such improvements include the gradual increase in the size of equipment and the gradual integration of computers into the production process. But no dramatic change in technology occurred in the middle 1980s that caused the productivity surges observed in some countries in Charts 4–11.[30]

Finally, while we have argued that there were no productivity gains in Australia and Brazil because mines in these countries faced little increase in competitive pressure, there is another possibility: perhaps there was no room for productivity gains in these countries. But that possibility can be ruled out. Both countries began experiencing dramatic productivity increases in the mid-1990s. (See Charts 4 and 5.)[31]

Conclusion

While a widespread view says that competitive pressure influences productivity, the evidence to support this view is not overwhelming. In our opinion, the sparsity of evidence most likely reflects the difficulties in demonstrating the connection between competitive pressure and productivity (and not that there is no connection). We have presented a case study—evidence from a particular industry during a particular time period—in which an increase in competitive pressure faced by producers, resulting from the shrinking of the producers' market, led to large gains in the labor productivity of those producers. We have also argued that those gains were driven by continuing establishments, producing the same products and using the same technology as they had before. In future work, we plan to study these sources of productivity gain in greater detail.

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[1]Regarding theoretical reasons to expect gains, a particularly interesting idea can be traced back more than 40 years to Becker (1959) and Alchian and Kessel (1962). It may be that a firm or industry with monopoly power faces restrictions on its ability to pay pecuniary returns to itself. Given this constraint, the monopoly chooses to take more return in nonpecuniary payoffs (like leisure on the job) than would otherwise be the case. As competition increases, some of these nonpecuniary returns are rolled back. (See more discussion on this below.) Good surveys on other ideas are found in Scherer and Ross 1990, pp. 667–72, and Nickell 1996. See Parente and Prescott 1999 for an interesting model. Regarding the evidence supporting the view that competitive pressure increases productivity, Scherer and Ross (1990, pp. 667–72) provide extensive references but still conclude that "the evidence is fragmentary," while Nickell (1996, p. 730) calls the evidence "very thin."

[2]Recent theoretical work illustrating connections between tariff reductions and productivity includes Holmes and Schmitz 2001 and Melitz 2002.

[3]Iron ore production in Brazil, Canada, and the United States was overwhelmingly in the eastern part of these countries, and we categorize them as Atlantic Basin countries.

[4]Perhaps the evidence is most mixed in the literature on trade liberalization. For example, Tybout, de Melo, and Corbo (1991) and Tybout and Westbrook (1995) find little relationship between reductions in tariffs (or in effective protection) across industries and changes in labor productivity. Rodriguez and Rodrik (1999) argue that there is little evidence that open trade policies are associated with good economic performance (though their study is at the national level and examines growth and not productivity). Yet MacDonald (1994) shows that increases in import penetration lead to productivity gains in concentrated industries while Ferreira and Rossi (2001) and Trefler (2001) provide evidence that tariff reductions lead to productivity gains at the industry level. Regarding the deregulation literature, there are surprisingly few detailed productivity studies. (For a good one, see Olley and Pakes 1996.)

[5]Changes in work rules may lead, for example, to increased effort per hour worked or improvements in how efficiently labor is utilized or both.

[6]We restrict attention to major producers because data for smaller producers are difficult to obtain. While statistics on iron ore production are readily available for nearly all countries, statistics on labor input are not. Labor input data had to be collected from statistical agencies in each country. Also, data on production costs at mines are only available for major producers.

[7]The next largest producers in 1980 after these eight are Liberia (17.4) and Venezuela (16.1). No other producer exceeded 10 million metric tons.

[8]Since there was not much trade in iron ore and steel between communist and noncommunist countries in the period we are studying, here we focus exclusively on noncommunist iron ore and steel producers.

[9]If the vast majority of the transport charges were port charges, then transport charges would not be significantly related to length of trip.

[10]We show data for 1994 because we have a large set of data on transport costs between locations for that year. In Table 3, we show less complete data on transport costs for the early 1980s. The two sets of data tell the same story regarding the size of transport costs relative to delivered prices.

[11]There are three major types of iron ore: lump, concentrates (or *fines*), and pellets.

[12]The transport charges from Brazil to Chicago were so high because the iron ore was first moved on massive oceangoing vessels and then on much smaller vessels that could travel the St. Lawrence Seaway. The charges per ton mile were much higher on the smaller vessels. Also, the iron ore faced two transfer charges (in the Brazilian port and in transferring to smaller vessels).

[13]Two pieces of evidence show that the 1974 drop was thought to be short-lived. First, there was an aggressive expansion of iron ore capacity in the late 1970s in many countries. In the United States, for example, two new mines opened in Minnesota, at Hibbing and Minorca, in the late 1970s. Existing Minnesota mines, such as Minntac, also expanded capacity. These openings and expansions increased capacity in Minnesota (which accounted for the majority of U.S. iron ore production) from roughly 41.2 million long tons in 1975 to 65.5 million long tons in 1980. (See Kakela, Kirsis, and Marcus 1987, Table Z-1-34.) Second, the behavior of iron ore prices shows that the crunch for iron ore producers did not arrive until the early 1980s. In particular, most iron ore prices increased through the 1970s, and not until the early 1980s, when the steel collapse became abundantly clear, did iron ore prices begin falling, on the order of from 20 percent to 33 percent over the period from 1982 to 1986. (See Galdón Sánchez and Schmitz 2000.)

[14]While we can ask about a mine's prospects following the steel production collapse under the assumption that its production costs and those of its rivals remain fixed, the steel production collapse may well have had an influence on transport prices for iron ore. While this must have been true to some extent, it is also true that ships that carry iron ore (dry bulk carriers) can also carry other dry bulk commodities like coal and grain. The ton miles of coal, grain, and iron ore transported in 1980 were of similar magnitudes. (See Figure 4 in Lundgren 1996.)

[15]As seen in what follows, it is easy to classify mines by the increase in competitive pressure they faced. It is not necessary to develop a formal model to calculate the probabilities of mine closure. One could imagine specifying a planner's problem in which the objective is to deliver iron ore to steel production centers at minimum cost (production plus transportation). The steel collapse would change the location of steel production and involve a change in the least-cost way to deliver iron ore to the steel centers.

[16]The production costs in Tables 3 and 4 are operating costs (roughly, variable costs) and do not include capital costs. Capital or capacity costs in iron ore mining are very large, but these were already sunk when the steel collapse hit the industry. What capacity survived the collapse depended on operating costs.

[17]After iron ore is mined, it nearly always undergoes some form of *beneficiation*—a process of crushing and screening the iron ore to produce uniformly sized particles, improve the iron content of the product, and eliminate impurities.

[18]The USBM report (Bolis and Bekkala 1987) also demonstrates that South Africa had significantly higher costs of producing concentrates (*fines*), the major South African product, than did Brazil. For example, Figure 19 (p. 33) in the report shows that Brazil had huge deposits of fines that could be mined at lower costs than the least-cost deposit in Africa (and, hence, South Africa). French mines were not studied in the report.

[19]In discussing production costs, we have been implicitly assuming that iron ore is a homogeneous product. It is not. Some beneficiated ore, that is, lump iron ore, could be used directly in blast furnaces. In the period we are studying, it sold for a premium over the other beneficiated iron ores, concentrates and pellet feed, that had to be further processed (namely, *agglomerated*). It turns out that not only did Australia, Brazil, and India have the lowest costs in producing beneficiated iron ore, but their beneficiated ore was worth more as well. That is because these countries had a much higher fraction of beneficiated iron ores that needed little or no agglomeration. Agglomeration costs were large. Concentrates were typically agglomerated at steel plants, while pellet feed was typically agglomerated into pellets at iron ore mines. That is the principal reason pellets sold for more than concentrates at iron ore mines (as seen in Table 2). See Galdón Sánchez and Schmitz 2000, in particular, Appendix B ("Prices of Beneficiated Iron-Ores"). Hence, considering differences in iron ore quality only strengthens the case we are making.

[20]The drop in Atlantic Basin steel production could have been so great that even Brazilian capacity could have been threatened with closure. But the drop was not this great.

[21]If one played devil's advocate and took the view that the iron ore industry had more than a negligible impact on steel industry developments in the early and middle 1980s, then one would have to explain the fact that the steel industry fell hardest in the areas where iron ore productivity increased the most.

[22]While a detailed discussion of theoretical reasons for this close connection are beyond the scope of this study, let us briefly return to an idea mentioned above. It may be that a firm or industry with monopoly power may face restrictions on its ability to pay pecuniary returns to itself. Given this constraint, the monopoly chooses to take more return in nonpecuniary payoffs than would otherwise be the case. This might be in the form of leisure (low effort) on the job or even redundant effort if jobs can be given to family, friends, and so on. In the case of iron ore, producers have monopoly power in their local area given that transportation costs typically loom very large in delivered charges. As for constraints on pecuniary payouts, mining is tied to the local area (because of the resources), so that the local political jurisdiction can extract significant portions of monetary profits. As competition increases, as the local monopoly power is reduced (as foreign producers now find it profitable to ship into the local area given that their markets elsewhere have shrunk), some of these nonpecuniary returns are rolled back. (For more theoretical discussion, see Schmitz 2001.) Note that this argument suggests that if an industry did not have much monopoly power in its local area, then if it faced an increase in competitive pressure, it would not respond by increasing productivity.

[23]While iron ore production recovered to about 80 percent of its precrisis level in Canada, Sweden, and the United States, so that many operations in those countries did ride out the crisis, the situation was touch-and-go for many operations that did survive. In the 1984 annual report of LKAB (p. 3), Sweden's leading iron ore producer, the company president, Wiking Sjöstrand, states that "Ten years ago, no one could imagine that LKAB might find itself involved in such a serious crisis as the one which we have just passed through . . . and in fact, for a period of time, a total catastrophe was very, very close." Wayne Dalke, who was the general manager of the U.S. Steel mine in Minnesota (Minntac) during the middle 1980s, told us that U.S. Steel was threatening to close the Minntac mine during the middle 1980s.

[24]Notes 1 and 22 suggested that if an industry did not have much monopoly power in its local area, then it would not increase productivity when it was threatened with closure. The French industry had little market power in its local area (that is, Northern Europe). Its iron ore was of very poor quality. The iron content of French iron ore (31.4 percent) was nearly half that of the eight top producers (61.7 percent). (See Table 1.) Another aspect of the French iron ore industry's problem was its location: it was located inland in the Lorraine, away from the modern coastal steel plants in Europe. (Thanks to a referee for this point.) There was nothing the French industry could have done to stave off disaster.

[25]In a nice study of productivity in coal mining, Ellerman, Stoker, and Berndt (2001) emphasize that during periods when coal prices decreased, marginal mines would close, and this led to increases in labor productivity. As just mentioned, closing of mines was not a factor in productivity gains in the U.S. iron ore industry in the 1980s. For a different view of the influence of changes in coal prices on coal productivity, see Prescott 1998.

[26]At least two pieces of evidence suggest that mine closings may not have been important in other countries either. First, the increase in productivity in these countries took place over the entire decade and were not concentrated in the initial period of steel production collapse when most mine closings likely took place. Second, in Canada and Sweden, industry production had returned to about 80 percent of its precrisis level by the end of the 1980s. That only about 20 percent of production was closed (and not, say, 80 percent of production) suggests that mine closings had only a modest contribution to increased productivity.

[27]Data are available only for four countries and at five-year intervals. While data are not available for South Africa, we know it essentially had no pellet production throughout the 1970–90 period.

[28]In Canada and Sweden, the move to pellets was greater in the 1980s than in the 1970s. In this sense, the productivity gains in the 1980s are understated relative to the productivity gains in the 1970s in these countries. For the United States, the opposite is true: the shift to pellets was greater in the 1970s than the 1980s. See Schmitz 2001 for a discussion of this.

[29]The major technological development in the postwar period was the production of pellets from low-grade iron ore, but this technology was developed by the late 1950s.

[30]There is a caveat. In contrast to the mines in the other top-producing countries, the Swedish mines were underground. Underground mining methods of all types (for example, of coal) and, in particular, of Swedish iron ore have changed significantly. See Hellmer 1997.

[31]What enabled Australia and Brazil to increase productivity in the mid-1990s but not in the early 1980s? While answering this question is beyond the scope of the study, we do know some facts that are highly suggestive. In the mid-1990s, Brazil began privatizing its iron ore industry. Changes in ownership likely spurred productivity gains. In Australia, many of the productivity gains in the 1990s have been attributed to changes in work rules. The Australian iron ore industry did attempt to change work rules in the early 1980s but was not successful. Two factors changed in the 1990s that may have led to the productivity gains. First, there was a general countrywide liberalization of labor laws in the 1990s. Second, there was a change specific to the industry: Australia's greatest competitor, Brazil, was experiencing significant productivity gains and was threatening to capture some of Australia's export market.

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Table 1

World Iron Ore Production in 1980

Area	1980 Production (Million Metric Tons) Reported by		1980 Metal Content Reported by USGS (% Iron)
	USGS	Country	
Top Noncommunist Producers			
Atlantic Basin			
Brazil	114.7	113.0	65.0
Canada	48.7	49.1	63.2
France	28.9	28.9	31.4
South Africa	26.3	26.3	63.9
Sweden	27.2	27.0	64.7
United States	70.7	70.7	63.1
Pacific Basin			
Australia	95.5	97.0*	63.2
India	41.9	41.6	62.5
Total	453.9	453.6	61.7
Other Totals			
Noncommunist Countries	558.8	—	60.8
Communist Countries	332.4	—	52.2
World	891.2	—	57.6

*Australia reported production for the financial year ended June 1980.
Sources: U.S., various years; Appendix

Table 2

Freight Rates and Delivered Prices of Iron Ore in 1994

			Freight Charges (U.S. $ Per Ton)					Delivered Prices (U.S. $ Per Ton) For This Type of Ore in This Market			
				From Port to This Destination							
				North America							
Country	Producer (Company)	Loading Port	From Mine by Rail to Port	Baltimore	Chicago	Northern Europe	Japan & Other Asia	Concentrates	Market	Pellets	Market
Australia	BHP	Port Hedland	2.25	11.55	n.a.	9.05	5.50	23.61	Japan	n.a.	n.a.
	Hamersley	Dampier	2.50	11.55	n.a.	9.05	5.50	23.85	Japan	n.a.	n.a.
	Robe River	Cape Lambert	1.75	11.55	n.a.	9.05	5.50	18.74	Japan	n.a.	n.a.
Brazil	CVRD	Ponta da Madeira	4.10	8.00	n.a.	6.30	9.60	28.23	Europe	n.a.	n.a.
	CVRD	Tubarão	3.50	8.50	24.35	6.50	10.30	26.40	Europe	38.03	Europe
	MBR	Sepetiba Bay	7.00	8.50	24.35	6.50	10.30	30.31	Europe	n.a.	n.a.
	Samitri	Tubarão	7.50	8.50	24.35	6.50	10.30	27.24	Europe	41.68	Europe
Canada	QCM	Port-Cartier	2.00	5.75	9.95	6.30	n.a.	25.59	Europe	36.94	Europe
	IOC	Sept-Îles	2.50	5.75	9.95	6.30	n.a.	26.02	Europe	37.66	Europe
	Wabush	Pointe-Noire	5.70	5.75	9.95	6.30	n.a.	28.48	Europe	43.87	N.Amer.
India	Kudremukh	Mangalore	1.50	11.55	n.a.	8.50	7.90	22.24	Japan	34.81	Japan
South Africa	Sishen	Saldanha Bay	7.50	10.75	n.a.	8.00	9.25	29.04	Europe	n.a.	n.a.
Sweden	LKAB	Narvik/Luleå	7.00	9.00	n.a.	3.35	n.a.	29.96	Europe	40.77	Europe
United States	Minnesota	Duluth	6.05	n.a.	6.79	n.a.	n.a.	n.a.	n.a.	43.43	N.Amer.

n.a. = not available
Source: Boyd and Perron 1997

Table 3

Costs of Producing and Transporting Iron Ore in 1984 . . .

Costs Estimated by the U.S. Bureau of Mines for Selected Iron Ore Mines

		Production Costs (U.S. $ Per Ton)				Transportation Costs						
						By Rail (From Mine to Port)			*By Ocean* (From Port to Destination)			
	Number of Mines	Mining		Beneficiation		U.S. $ Per Ton Km.		Distance	U.S. $ Per Ton			Ship Size (Thou. Dead-
Country	Studied	Low	High	Low	High	Low	High	(Km.)	Low	High	Destination	weight Tons)
Atlantic Basin												
Brazil	13	.70	2.00	.50	1.70	.005	.007	640–730	7.00	9.00	Japan	130–150
									5.25	6.00	Japan	220
									5.75	6.50	W. Europe	50–65
									4.50	6.00	W. Europe	80–155
Canada	3	2.00	2.50	3.00	3.50	.008	.009	410–450	n.a.	n.a.	Japan	130–150
									3.00	4.25	W. Europe	100–160
Europe*	5	2.60	7.20	1.50	4.50	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
United States	9	2.00	4.50	3.25	5.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Pacific Basin												
Australia	5	1.60	2.60	.30	1.60	.003	.004	50–430	5.00	6.00	S. Korea	100–150
									6.50	8.75	W. Europe	100–150
India	5	1.00	5.00	.50	1.50	.020**	n.a.	60–470	n.a.	n.a.	n.a.	n.a.

n.a. = not available

* The European countries included in the study are Norway, Spain, and Sweden.

**India's rail transport costs from mines to ports are reported as an average rather than a range.

Source: Bolis and Bekkala 1987

Table 4

. . . And in 1994

Costs Estimated by Natural Resources Canada for Selected Iron Ore Mines

		U.S. $ Per Ton		
		Production Costs* (Concentrates Only)	Transportation Costs	
Country	Producer (Company)		*By Rail* From Mine to Port	*By Ocean* From Port to N. Europe
Atlantic Basin				
Brazil	CVRD, Carajás	2.15	4.10	6.30
	CVRD, Minas Gerais	3.15	3.50	6.50
	MBR	2.50	7.00	6.50
	Samitri	2.95	7.50	6.50
Canada	QCM	9.20	2.00	6.30
	IOC	10.85	2.50	6.30
	Wabush	9.05	5.70	6.30
South Africa	Sishen	8.80	7.50	8.00
Sweden	LKAB	10.50	7.00	3.35
Pacific Basin				
Australia	BHP	7.95	2.25	9.05
	Hamersley	4.15	2.50	9.05
	Robe River	3.50	1.75	9.05
India	Kudremukh	6.35	1.50	8.50

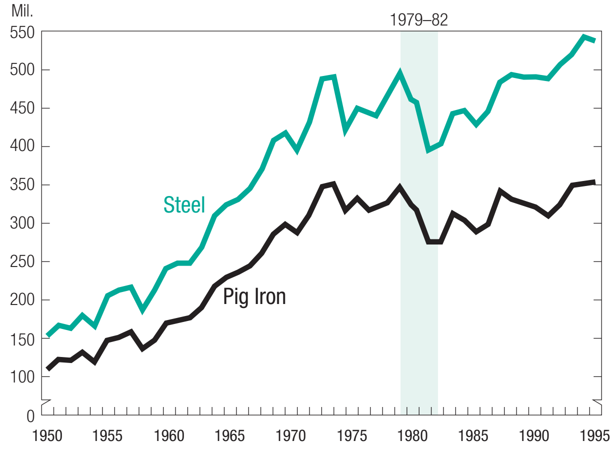
*Production costs here may include more than the mining and beneficiation costs on Table 3, such as the costs of agglomeration.

Source: Boyd and Perron 1997

Chart 1

World Steel and Pig Iron Production

In Noncommunist Countries, Annually, 1950–96, Millions of Metric Tons



Source: U.S., various years

Charts 2 and 3

Regional Pig Iron Production

Annually, 1950–96, Millions of Metric Tons

Chart 2 In the Atlantic and Pacific Basins

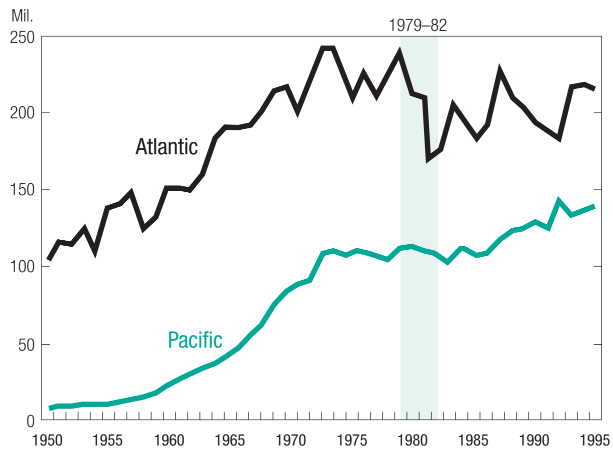
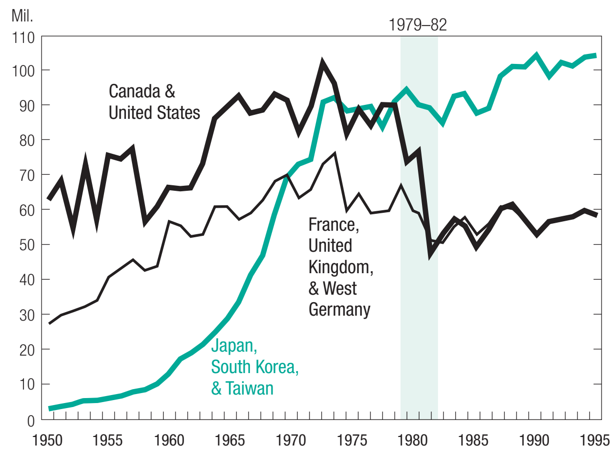


Chart 3 In Other Groups of Countries

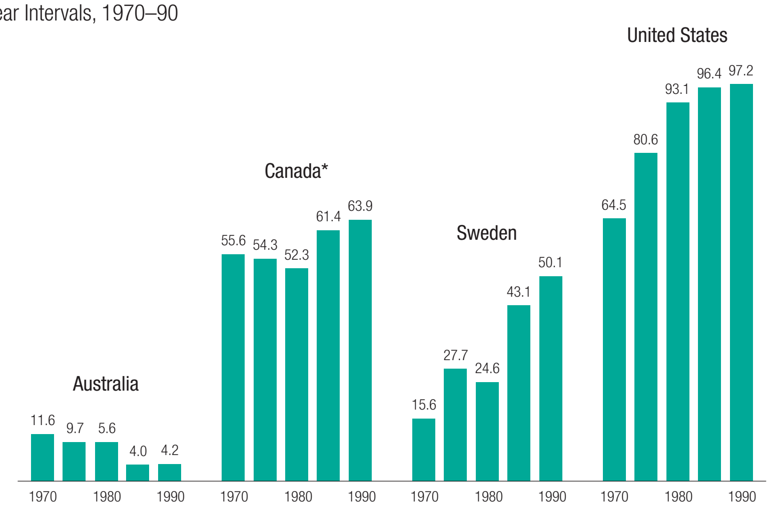


Source: U.S., various years

Chart 12

A General Shift to a More Labor-Intensive Product

Pellets as a Percentage of Iron Ore Production (by Weight)
in Four Countries, Over Five-Year Intervals, 1970–90



*Canada's data are percentages of shipments, not production.
Sources: United Nations 1994; U.S., various years