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 little, if any, productivity gains. The closing of low productivity mines, shifts in the types of iron-ore produced, and the introduction of new technology were not important sources of productivity gains in the Atlantic mines.

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 accounts, 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 as well); 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. As in the case of France, we do not expect that 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 should not increase competitive pressure (see, e.g., 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 in the future 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 in these industries is often difficult.[4] Perhaps because of these and other difficulties, there is not overwhelmingly support that these policies lead to significant productivity gains.[5]

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 (firms are 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 (2001) 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).[6]

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.)[7] 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 output and productivity records of the top iron-ore producing countries. We then briefly discuss the sources of the productivity gains and conclude.

I. 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 top producers of iron-ore in 1980 are listed in Table 1.[8] The second column lists each country's iron-ore production in 1980 as given by the United States Geological Survey (USGS).[9] Total USGS-production in 1980 for these eight countries was about 81 percent of total noncommunist production.[10] The third column lists country-reported production. The last column is the percentage of iron in the iron-ore of each country.

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.[11] These features can be seen in Table 2 which shows rail transport costs and ocean freight costs for selected iron-ore mines in 1994.[12] The first column shows the average rates per ton for rail transport

of iron-ore from mines to port of export. Columns two through five show the average charges for ocean transport from port of export to various markets around the world. The last two columns show delivered prices for two types of iron-ore, concentrates and pellets.[13] 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 71 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 twice the charge per ton to Japan ($11.55 versus $5.50). The average charge per ton to Northern Europe was 60 percent greater than the charge per ton to Japan ($9.05 versus $5.50).[14]

When iron-ore is used to make steel, it is first turned into pig iron. Hence, a direct measure of the use of iron-ore by steel producers is the production of pig iron. We plot the world production of steel and pig iron in Figure 1. The collapse of world steel production in the early 1980s is evident. From 1979 to 1982, steel production dropped 20 percent. Production did not reach 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.

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.[15] But the drop in the early 1980s was different: it became clear that some mines would need to be closed. But which ones would close?

II. 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.

A. 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 (by the term "path" we mean how much, and where, steel is produced) changed significantly. 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.[16] 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 now faced much dimmer prospects, 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.[17]

B. Atlantic Basin Collapse

The drop in steel and pig iron production between 1979 and 1982 was concentrated in the Atlantic Basin. In the top panel of Figure 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 Mmt 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.

The bottom panel of Figure 2 shows pig iron production for various groups of countries. Between 1979 and 1982, the sum of Canadian and U.S. production fell by 50 percent; in France, the United Kingdom, and West Germany, production fell by over 20 percent; and in Japan, South Korea, and Taiwan, production fell very little by comparison.

C. Production Costs

A major effort to estimate mine production costs in the early 1980s was made by the U.S. Bureau of Mines (USBM). USBM-estimated production, or operating, costs at mines are given in the left-most columns of Table 3.[18] Costs were estimated at a number of mines in each country (or region). The first column 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 (the second and third columns, respectively).[19] The USBM report (Bolis and Bekkala 1987) presents only the range of costs in each country.

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 to $2.00 per ton) was everywhere

below the range in Canada ($2.00 to $2.50), Europe ($2.60 to $7.20), and the United States ($2.00 to $4.50). The Swedish mines were underground, so the $7.20 mining cost in Europe clearly belonged to Sweden. The range of beneficiation costs in Brazil ($0.50 to $1.70 per ton) was everywhere below the range in Canada ($3.00 to $3.50) and the United States ($3.25 to $5.00) and nearly so in Europe ($1.50 to $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.[20]

The bottom of Table 3 shows data for Pacific Basin mines. Production costs in those countries were much lower than 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 to $1.70 per ton) was similar to that in Australia ($0.30 to $1.60) and India ($0.50 to $1.50), mining costs in Brazil ($0.70 to $2.00) were somewhat lower than in Australia ($1.60 to $2.60) and India ($1.00 to $5.00)).[21]

Another major effort to estimate production costs was undertaken by Natural Resources Canada (NRC) in the middle 1990s. While the NRC (Boyd and Perron 1997) 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. The first column in Table 4 shows the operating costs (mining plus beneficiation) 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 had the lowest-cost mines.

D. Classifying Mines

Given this information on the location of the steel collapse and 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.[22]

Consider the Brazilian and Canadian mines as competitors in Europe using Table 3. 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.

The right-most column of Table 3 shows ocean freight costs from the USBM study. 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 10^3 DWT compared to \$3.00 on a ship of size 160 10^3 DWT). This difference of \$1.50 is just a bit bigger than the (minimum) Brazilian 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 charges to Europe were similar).

Now compare Brazilian and Swedish mines. The highest production cost for a Brazilian mine was again \$3.70, while the lowest cost for a Swedish mine was \$8.70 (\$7.20+\$1.50). Brazilian mines 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 using Table 4. Brazil could produce and ship to Northern Europe in 1994 at less cost than Canada and Sweden.

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.[23]

III. Competitive Pressure 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.[24]

The top part of Figure 3 shows the countries where mines faced little or no increase in competitive pressure. The bottom part of the figure shows 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.

In the early 1980s, production fell little in Australia, Brazil, and India compared to the five producers in the bottom panel of Figure 3. 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, output 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 in France it dropped through the decade.[25]

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 as well). 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. France had no gains over the 1980s.

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.[26]

IV. Sources of Productivity Gains

In this section, we briefly argue that the productivity gains observed in Figure 3 were driven by continuing mines, producing the same products, and using the same technology. 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 decomposition, Schmitz (2001) shows that the closing of mines contributed between 0 and 7 percent (depending on the years) to industry productivity gains.[27] We conjecture that mine closings contributed little in other countries as well, although this must await future research.[28]

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. Table 5 shows pellet production as a percentage of total iron-ore production in 1970–90 in four countries.[29] Over the period, there was a shift toward pellets in Canada, Sweden, and the United States. So, everything else equal, productivity in the 1980s in these countries should have been lower than in the 1970s. This 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 Figure 3 for these three countries are understated.

New technology also contributed little to the gains. The technology in this mature industry changes very slowly.[30] 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 Figure 3.[31]

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 Figure 3.) [32]

V. Conclusion

While a widespread view says that competitive pressure influences productivity, the evidence to support this view is not overwhelming. In our opinion, this 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 where 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 mines, producing the same products, and using the same technology. In future work, we plan to study these sources of productivity gain in greater detail.

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Notes

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[1]Regarding theoretical reasons to expect gains, a particularly interesting idea can be traced back forty years to Becker (1957) and Alchian and Kessel (1962). It may be that a firm or industry with monopoly power may face restricions on its ability to pay pecuniary returns to itself. Given this constraint, the monopoly chooses to take more return in non-pecuniary payoffs (like leisure on the job) than would otherwise be the case. As competition increases, some of these non-pecuniary returns are rolled back (see more discussion on this below). Good surveys on other ideas are found in Scherer and Ross (1990, pp. 667-672) and Nickell (1996). See Parente and Precott (1999) for an interesting model. Regarding the evidence supporting the view that competitive pressure increases productivity, Scherer and Ross (1990, pp. 667-672) provide extensive references but still conclude that "the evidence is fragmentary," while Nickell calls the evidence "very thin."

[2]Recent theoretical papers illustrating connections between tariff reductions and productivity include Melitz (1999) and Holmes and Schmitz (2001).

[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]For a discussion of these difficulties, and others, in the privatization literature, see Megginson and Netter (2001), for example, p. 332 and p. 346.

[5]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). On the other hand, MacDonald (1994) shows that increases in import penetration lead to productivity gains in concentrated industries while Ferreira and Rossi (2001) and Treffler (2001) provide evidence that tariff reductions lead to productivity gains at the industry level. Regarding the deregulation literature, there are surprisingly few (to us) detailed productivity studies (for a good one see Olley and Pakes 1996).

[6]See also the work of Baily (1993) and Baily and Gersbach (1995).

[7]Changes in work rules may lead, for example, to increased effort per hour worked and/or to reductions in redundant effort.

[8]We restrict attention to major producers because data for smaller producers are dif-

ficult 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.

[9]The next largest producers in 1980 after these eight were Liberia (17.4) and Venezuela (16.1). No other producer exceeded 10 Mmt.

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

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

[12]We show data for 1994 because we have a large set of data on transport costs between locations for that date. 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.

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

[14]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 boats. Also, the iron-ore faced two transfer charges (in the Brazilian port and in transferring to smaller boats).

[15]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 20 percent to 33 percent over the period from 1982 to 1986. See Galdon-Sanchez and Schmitz (2000).

[16]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, Lundgren (1996)).

[17]As seen below, it's 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 where the objective is to deliver iron-ore to steel production centers at mininum 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.

[18]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.

[19]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.

[20]The USBM report 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.

[21]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. It sold for a premium over the other beneficiated iron-ores, concentrates and pellet feed, that had to be further processed (namely, agglomerated). Concentrates were typically agglomerated at steel plants, while pellet feed was typically agglomerated into

pellets at iron-ore mines. That is the principal reason why pellets sold for more at iron-ore mines than concentrates (as seen in Table 2). It turns out that Australia, Brazil, and India not only had the lowest costs in producing beneficiated iron-ore, but their beneficiated ore was worth more as well. See Galdon-Sanchez 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.

[22]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.

[23]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 to mid 1980s then one would have to reconcile the fact that the steel industry fell hardest in the areas where iron-ore productivity increased the most.

[24]While a detailed discussion of theoretical reasons for this close connection are beyond the scope of this paper, let us briefly return to an idea mentioned above. It may be that a firm or industry with monopoly power may face restricions on its ability to pay pecuniary returns to itself. Given this constraint, the monopoly chooses to take more return in non-pecuniary 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, etc. In the case of iron-ore, producers have monopoly power in their local area given that transportation costs typicaly 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 their markets elsewhere have shrunk), some of these non-pecuniary returns are rolled back (for more 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.

[25]While output recovered to about 80 percent of its precrisis level in these last three countries, so that many operations in Canada, Sweden, and the United States did ride out the crisis, the situation was touch-and-go for many that did survive. In the 1984 annual report of LKAB, Sweden's leading iron-ore producer, the company president, Wiking Sjostrand, stated: "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" (*LKAB Annual Report, p. 3*). 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.

[26]The note above suggested that if an industry did not have much monopoly power in its local area then it would not increase productivity as it was threatened with closure. The French industry had little market power in its local area (i.e. 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 other 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 information.) There was nothing the French industry could have done to stave off disaster.

[27]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).

[28]Two pieces of evidence suggest that mine closings may not have been important in other countries as well. 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.

[29]Data are available for only 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.

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

[31]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, coal) and, in particular, of Swedish iron-ore have changed significantly. (See Hellmer 1997.)

[32]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 paper, 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 changes. First, there was a general country-wide 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.

Table 1

Top Eight Iron-Ore Producers and Some Characteristics
of Their Iron-Ore Production in 1980

Countries	**Years***	**USGS Production—1980** (million metric tons)	**Country-reported Production—1980** (million metric tons)	**USGS Metal Content—1980** (percentage iron)
Atlantic Basin				
Brazil	1972–95	114.7	113.0	65.0
Canada	1961–97	48.7	49.1	63.2
France	1970–94	28.9	28.9	31.4
South Africa	1980–97	26.3	26.3	63.9
Sweden	1965–93	27.2	27.0	64.7
U.S.A.	1965–97	70.7	70.7	63.1
Pacific Basin				
Australia	1966–97	95.5	97.0**	63.2
India	1965–95	41.9	41.6	62.5
Total, Top Eight Producers		453.9		61.7
Total noncommunist		558.8		60.8
Total communist		332.4		52.2
Total World		891.2		57.6

*For which labor input data are available.

**For financial year ending June 30.

Sources: Australia: Production and employment from *Manufacturing Census,* Australian Bureau of Statistics. Brazil: Production and employment from *Anuario Mineral Brasileiro,* Departmento Nacional de Produção Mineral, Ministério de Minas e Energia. Canada: Production and employment from *Canadian Minerals Yearbook,* Natural Resources Canada. France: Production from *Minerals Yearbook,* United States Geological Survey. Employment from *INSEE,* National Accounts Department. India: Production and employment from *Indian Minerals Yearbook,* Indian Bureau of Mines, Ministry of Steel and Mines. Also data from Federation of Indian Mineral Industries. South Africa: Production and employment from *South Africa's Mineral Industry,* Minerals Bureau, Department of Minerals and Energy. Sweden: Production from *Minerals Yearbook,* United States Geological Survey. Employment and hours worked from *Statistics Sweden* (Statistika centralbyran). United States: Production, employment, and hours worked from *Minerals Yearbook,* United States Geological Survey.

Table 2

Freight Rates and Prices for Iron-Ore in 1994

Country	Producer	Loading Port	Freight: Rail to Port	Freight: Port to Destination: North America: Baltimore	Freight: Port to Destination: North America: Chicago	Freight: Port to Destination: Northern Europe	Freight: Port to Destination: Japan and Other Asia	Price[1] (concentrates)	Price[1] (pellets)
			(US$/t)[2]			(US$/t)[2]		(US$/t)[2]	(US$/t)[2]
Australia	BHP	Port Hedland	2.25	11.55	–	9.05	5.50	23.61 (J)	na
	Hamersley	Dampier	2.50	11.55	–	9.05	5.50	23.85 (J)	na
	Robe River	Cape Lambert	1.75	11.55	–	9.05	5.50	18.74 (J)	na
Brazil	CVRD	Ponta da Madeira	4.10	8.00	nr	6.30	9.60	28.23 (E)	
	CVRD	Tubarao	3.50	8.50	24.35	6.50	10.30	26.40 (E)	38.03 (E)
	MBR	Sepetiba Bay	7.00	8.50	24.35	6.50	10.30	30.31 (E)	na
	Samitri	Tubarao	7.50	8.50	24.35	6.50	10.30	27.24 (E)	41.68 (E)
Canada	QCM	Port-Cartier	2.00	5.75	9.95	6.30	–	25.59 (E)	36.94 (E)
	IOC	Sept-Îles	2.50	5.75	9.95	6.30	…	26.02 (E)	37.66 (E)
	Wabush	Pointe-Noire	5.70	5.75	9.95	6.30	–	28.48 (E)	43.87 (NA)
India	Kudremukh	Mangalore	1.50	11.55	–	8.50	7.90	22.24 (J)	34.81 (J)
So. Africa	Sishen	Saldanha Bay	7.50	10.75	–	8.00	9.25	29.04 (E)	na
Sweden	LKAB	Narvik/Lulea	7.00	9.00	–	3.35	–	29.96 (E)	40.77 (E)
United States	Minnesota	Duluth	6.05	–	6.79	–	–	na	43.43 (NA)

[1] Delivered price in the producer's largest market. E = Europe, J = Japan, NA = North America.

[2] U.S. dollars per ton of iron-ore.

–Nil, or no significant trade.

…There was some trade on this route, but freight rate is not a market rate.

nr—not reported; na—not applicable.

Source: Boyd and Perron (1997).

Table 3

Production Costs, Rail Transport Costs, and
Ocean Freight Costs for Selected Iron-Ore Mines, 1984

Country	Number of Mines	Production Costs U.S. $/t		Rail Transport Costs		Ocean Freight Costs		
		Mine	Beneficiation	U.S. $/t km	Distance, km	Destination	Ship Size 10^3 DWT	U.S. $/t
Atlantic Basin								
Canada	3	2.00–2.50	3.00–3.50	.008–.009	410–450	Japan	130–150	…..
						Western Europe	100–160	3–4.25
Europe[1]	5	2.60–7.20	1.50–4.50					
United States	9	2.00–4.50	3.25–5.00					
Brazil	13	.70–2.00	.50–1.70	.005–.007	640–730	Japan	130–150	7–9
							220	5.25–6
						Western Europe	50–65	5.75–6.50
							80–155	4.50–6.00
Pacific Basin								
Australia	5	1.60–2.60	.30–1.60	.003–.004	50–430	South Korea	100–150	5–6
						Western Europe	100–150	6.50–8.75
India	5	1.00–5.00	.50–1.50	.020(av)	60–470			

….. There was some trade on this route, but freight rate is not a market rate.

[1] European producers include Norway, Spain, and Sweden.

Source: Bolis and Bekkala (1987).

Table 4

Production Costs for Concentrates, Rail Transport Costs,
and Ocean Freight Costs to Northern Europe for Selected Iron-Ore Mines, 1994

Country	Producer	Production Costs U.S. $/t	Rail Transport Costs U.S. $/t	Ocean Freight Costs to Northern Europe U.S. $/t
Atlantic Basin				
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
Brazil	CVRD—Carajas	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
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

Source: Boyd and Perron (1997)

Table 5

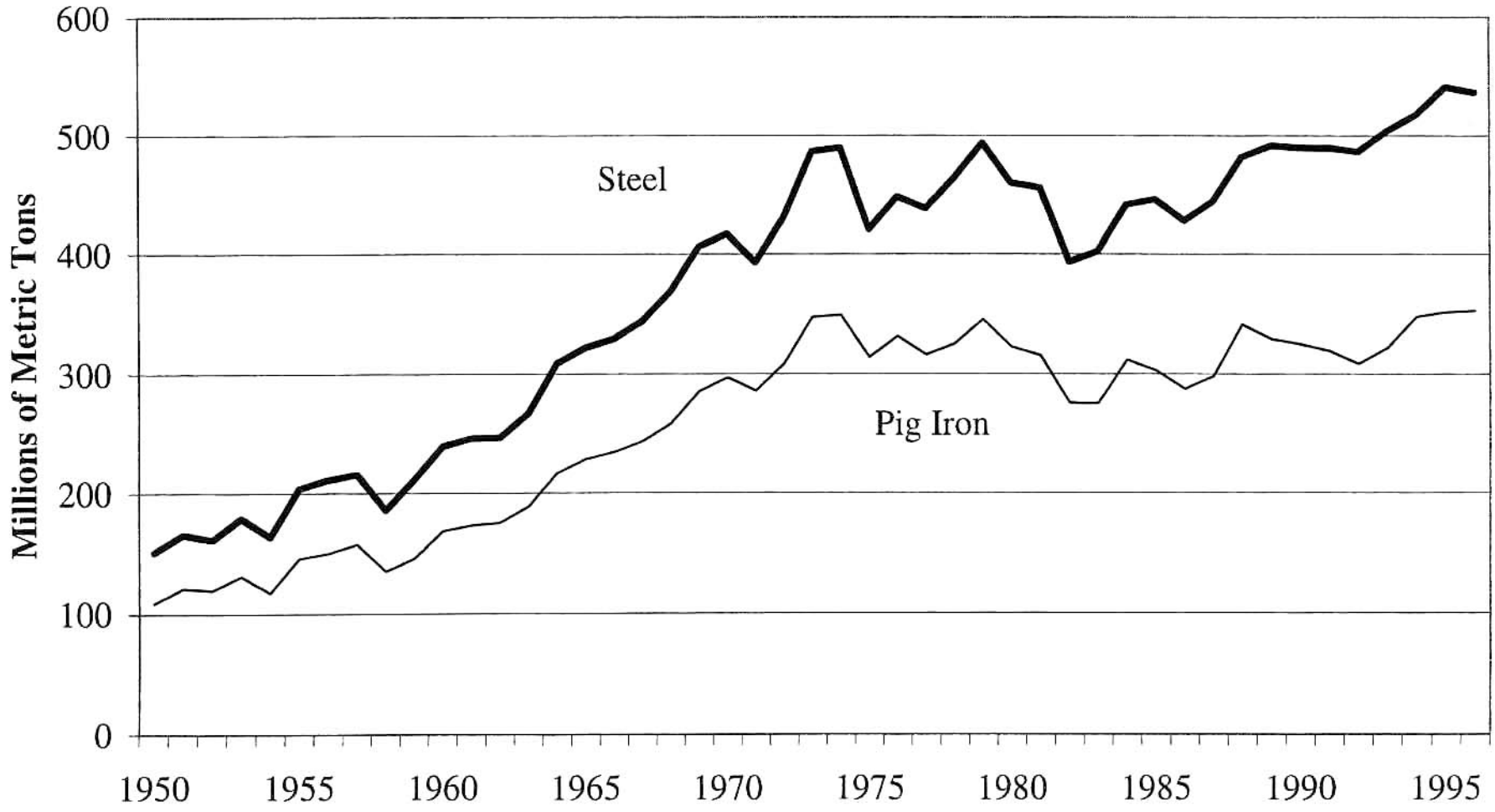
Pellet Production as a Percentage of Total Iron-Ore Production (by Weight)

	Country			
Year	Australia	Canada[1]	Sweden	United States
1970	11.6	55.6	15.6	64.5
1975	9.7	54.3	27.7	80.6
1980	5.6	52.3	24.6	93.1
1985	4.0	61.4	43.1	96.4
1990	4.2	63.9	50.1	97.2

[1] Percentage of shipments

Source: United States: *Minerals Yearbook* of USGS
Other countries: United Nations (1994)

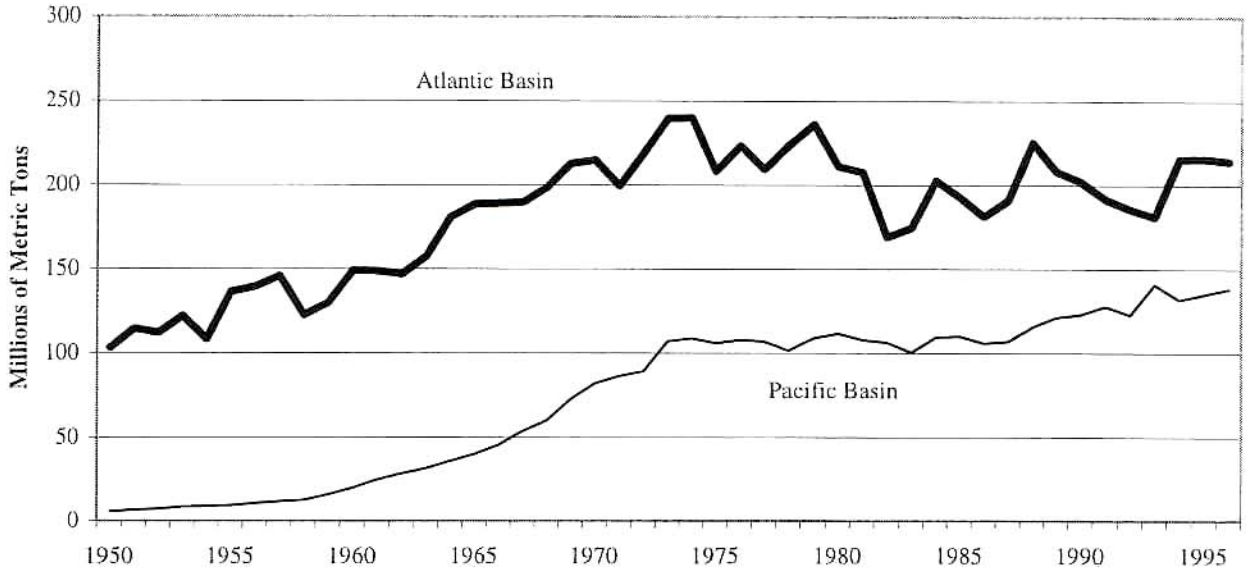
Figure 1: World Steel and Pig Iron Production*
1950-96



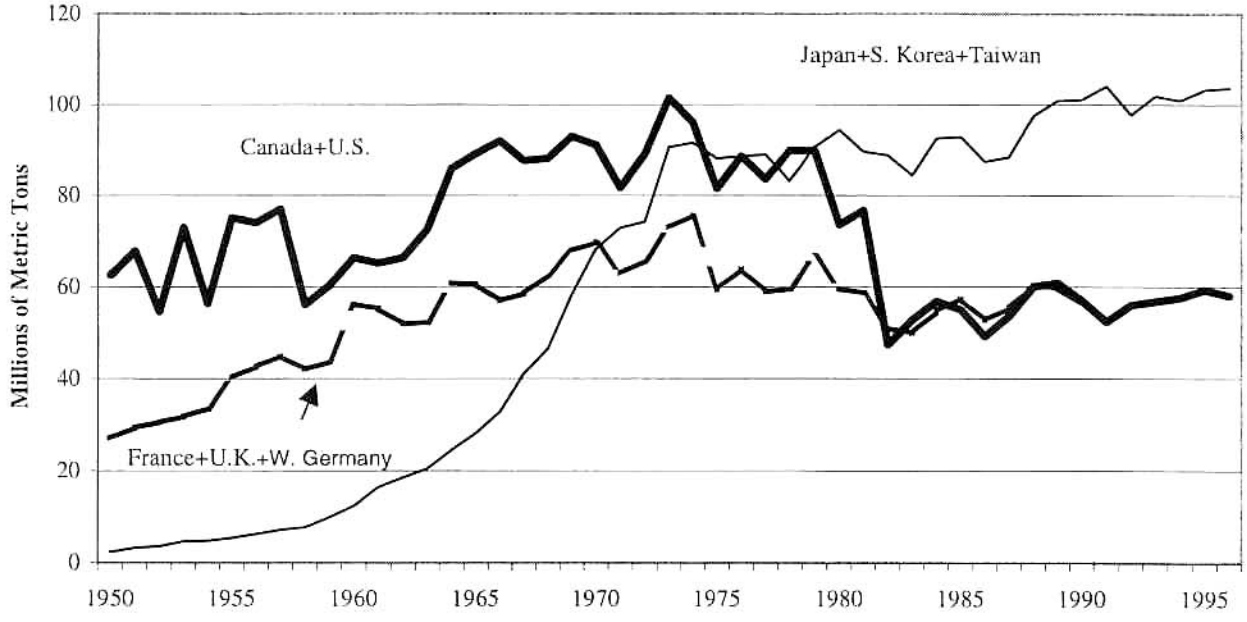
* Noncommunist countries.
Source: USGS (Various Years)

Figure 2: Pig Iron Production 1950-96

By Basin

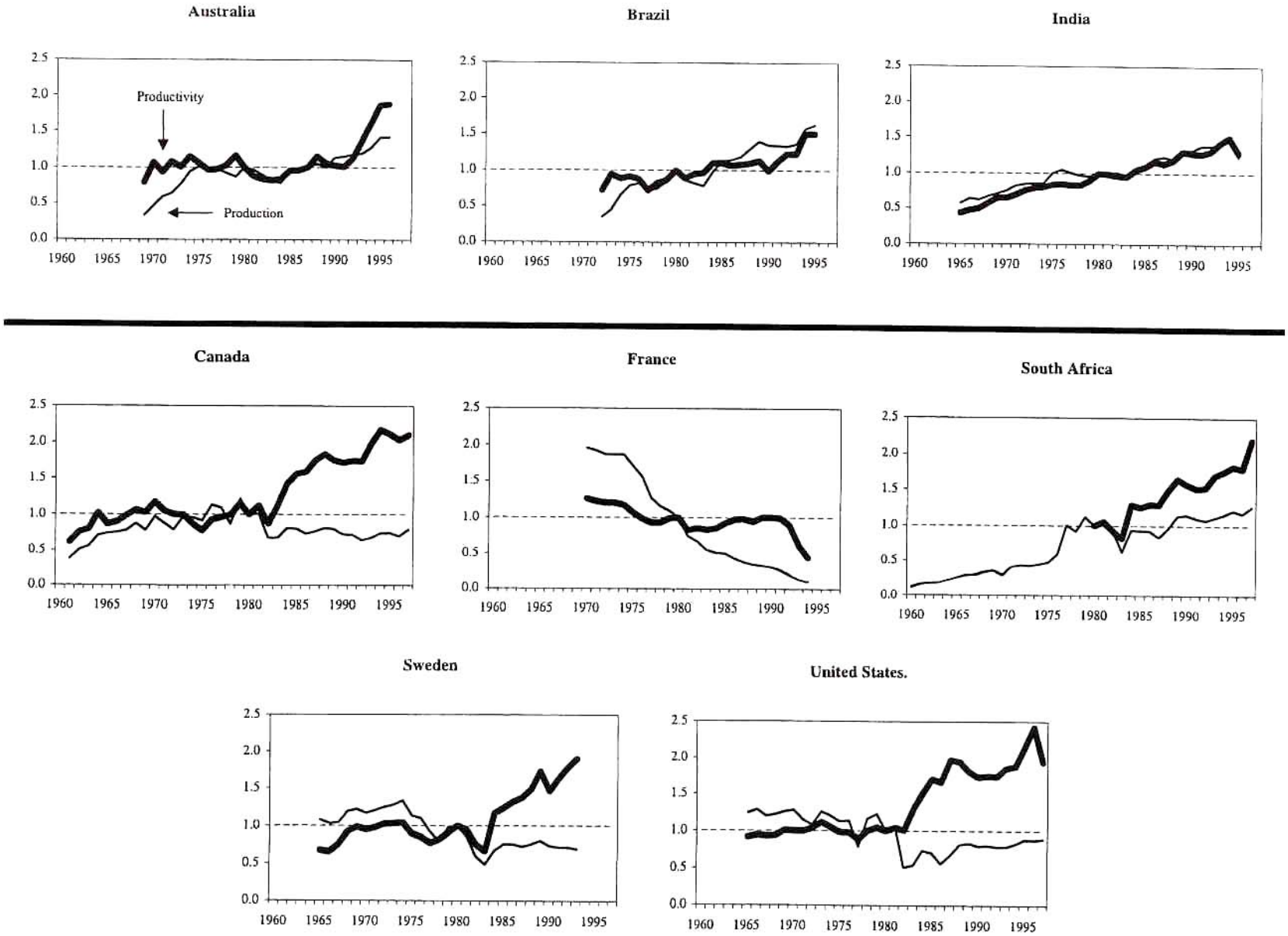


By Groups of Countries



Source: USGS (Various Years)

Figure 3: Iron-Ore Production and Productivity (1980 = 1)
By Increase in Competitive Pressure: Top Panel - Little or No Increase, Bottom Panel - Significant Increase



Source: See notes to Table 1.