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Keywords
Financial market crises, Debt crises, Government budget constraint, Exhaustible resources, Resource depletion

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Abstract

During a financial crisis, the loss of access to world capital markets may force heavily indebted countries to accelerate their production of exhaustible resources. Few studies consider the impact that financial crises have on real behavior, and no existing studies appear to consider the impact a crisis might have on resource production. We find that four major state-owned enterprises in Brazil, Chile and Mexico substantially expanded their production and world market share of copper, iron ore and oil during the 1980s international financial crisis. There was also a very large expansion, followed by a sharp contraction, of production of tin in Brazil and silver in Mexico. In contrast, Indonesia – a major resource producer who did not succumb to the 1980s financial crisis – did not accelerate production during the 1980s crisis, and resource production in the U.S. sharply contracted during this period. Our study provides new insights into why the prices of natural resources are so volatile and highlights a previously unexplored reason for financial contagion: one country's efforts to service its debt can drive down resource prices and revenues to other indebted resource producers.

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I. Introduction

Do financial crises accelerate the production of exhaustible resources? There are two main reasons why financial crises might impact natural resource production, particularly in developing countries. The most basic reason is that loss of access to world capital markets should substantially increase the shadow cost of capital, which in turn increases the value of current production relative to future production. A second reason is that financial crises should tighten the budget constraints of governments who rely heavily on international credit to balance their budgets. Cessation of new lending during a financial crisis may force indebted countries to expand the production of natural resources in order to generate the extra revenue required to avoid defaulting on public debt. Sovereign nations have strong incentives to avoid defaulting on their debt both because nations want to maintain access to new international loans (e.g., Eaton and Gersovitz, 1981) and remain engaged in international trade (e.g., Obstfeld and Rogoff, 1996).[1]

To our knowledge, no previous empirical studies have considered how financial crises might impact resource production. This is surprising, as financial crises are common, can be long lasting, and often occur in countries which are major exporters of natural resources.[2] Indeed, much of the developing world faced a severe financial crisis in 2008-2009 with frozen international capital markets and drastically curtailed issuance of new loans.[3] Furthermore, history shows that during times of emergency (e.g., wars), countries can quickly and dramatically expand (and contract) the production of minerals such as copper, tin and iron ore.[4] If financial crises do cause some countries to expand

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[1] Obstfeld and Rogoff (1996) note that sovereign defaults are almost always partial, rather than complete, suggesting that many nations facing financial crises do not readily repudiate their debts. Eichengreen and Portes (1986) report that countries they classify as "heavy defaulters" in the 1930s did not reenter the world capital market until the 1970s. A recent example is Argentina's loss of access to world capital markets following its default in 2001. Rose (2005) finds that sovereign debt renegotiations result in a substantial decline in trade that persists for around fifteen years.

[2] See Reinhart, Rogoff and Savastano (2003) for an overview of sovereign debt defaults in recent decades. See Sachs (2002) for a list of fifty-nine countries that required a Paris Club restructuring of their debt during 1975-96. See Sohn (1988) for a list of developing countries where a small number of minerals were the primary export.

[3] See, for example, the discussion in "Sovereign Debt Risk Looms Large This Year," *Wall Street Journal*, January 30, 2009.

[4] For example, between 1914 and 1916 (World War I), the U.S. expanded copper production by nearly 50%, reaching production figures 40% higher than the previous record; after 1918, production levels

natural resource production, there are many important implications, including a better understanding of why mineral prices are so volatile and new insights about the causes of financial contagion.

Our study fits within a sizable literature that evaluates the impact of financial crises. As Kroszner, Laeven and Klingebiel (2007) discuss, almost all of this literature focuses on the *financial* side of the economy. For example, prior studies have explored the impact of financial crises on foreign currency flows and exchange rate dynamics (e.g., Phylaktis and Ravazzolo, 2005), the behavior of index futures prices (e.g., Hassan et al., 2008), capital flows (e.g., Gerlach et al., 2006), stock market values (e.g., Cornell and Shapiro, 1986; Kyle and Wirick, 1990), and the provision of trade credit (Love et al., 2007). Kroszner, Laeven and Klingebiel (2007) also note that there is almost no empirical evidence on the channels through which financial crises impact *real* economic behavior; the one exception is their study on the impact of banking crises on industrial growth. Our study adds to this limited literature on financial crises and the real side of the economy.

We explore how the international financial crisis of the 1980s impacted resource production in key Latin American countries. This crisis is particularly well-suited for our purposes because it was very pronounced and the dating of the crisis is quite precise: it began with Mexico's default in 1982 and ended rather abruptly with the Brady Plan in 1989. The center of the crisis was Latin America, where many countries lost access to international capital markets during the 1980s. Only a small number of these countries, however, are good candidates for our study. In particular, to isolate the impact of the financial crisis we need countries that: i) had steady access to international capital markets *prior* to the 1980s debt crisis, and ii) were important producers of natural resources. The Latin American countries with ready access to international capital markets prior to the crisis were Argentina, Brazil, Chile, Columbia, Mexico and Venezuela. These were the larger, more developed economies in Latin America in the 1970s. Argentina and Columbia, however, were not major producers of minerals or fossil fuels at the start of the debt crisis. Venezuela was a major producer of petroleum, but it

immediately declined to prewar levels. Similar large swings in production occurred for copper in World War II and for iron ore and tin in both wars.

was a member of OPEC, which set Venezuela's production quotas during the crisis. Two other countries worth noting are Bolivia and Peru, both of which relied very heavily on mineral production as a source of foreign exchange and government revenue. Both countries, however, enacted a moratorium on debt re-payments to commercial banks in the mid 1980s. We discuss Bolivia and Peru in some detail at the end of the paper. The rest of Latin America consisted either of resource poor economies (e.g., Costa Rica, Dominican Republic, El Salvador, Honduras, Panama, Uruguay) or relatively poor countries with little or no access to international capital markets (e.g., Haiti, Nicaragua, Paraguay).

We thus focus on Brazil, Chile and Mexico, important resource producers who lost access to international capital markets in the 1980s but quickly regained access following the conclusion of the crisis. Each of these countries had large debt burdens and is widely identified (e.g, Cline, 1995 and Kamin, 1999) as being significantly affected by the 1980s international debt crisis. While all three countries had great difficulty servicing debt burdens during the 1980s, these countries were not in "chronic financial crisis," as were many developing countries, including several in Latin America (see Sachs (2002) for a long list of countries in chronic crisis).[5] For each country, we selected major minerals where the country was both a leading producer in Latin America and a significant world producer during the period we study. For Brazil, we examine iron ore, manganese, and tin. Brazil was the world's leading exporter of iron ore at the time of the 1980s financial crisis and briefly became the leading producer of tin. For Chile and Mexico, we examine copper and silver, respectively, and both countries were the world's leading producers at the start of the financial crisis. In addition to these five minerals, we also examine oil production, which was very important for the governments of both Brazil and Mexico. Each of the three countries had one or more major state-owned companies that were a critical source of revenue and foreign exchange. In four of the above seven cases, we have annual production figures for individual state-owned companies: iron ore production for CVRD in Brazil, copper production for CODELCO in

[5] Sachs (2002) examined fifty-nine developing countries that rescheduled their debt in the Paris Club during 1975-96. He classified thirty-nine of these countries (but not Brazil, Chile and Mexico) as in "chronic financial crisis." Resource producers in Latin America in "chronic crisis" include Bolivia and Ecuador.

Chile, and oil production for PEMEX and PETROBRAS, the oil monopolies in Mexico and Brazil. We are particularly interested in these four cases as most of the debt in Brazil, Chile and Mexico was either held directly by the public sector or was publicly guaranteed.

Plots of our data show that during the 1980s financial crisis both production and world-market share increased substantially, and sometimes dramatically, for iron ore, copper, tin and silver. Furthermore, production and world market share remain well above trend during the financial crisis but decline sharply at the conclusion of the crisis, suggesting that the initial rise in production was not a coincidence. The most dramatic example is Brazil's tin production, which increased by over 400% between 1982 and 1989, and then collapsed after 1991. For oil, Mexico's production nearly doubles in the early 1980s, while Brazil's production and world market share jumps nearly three fold between 1982 and 1987. In addition, neither country cuts production in response to the very sharp fall in oil prices in the middle of the crisis (1986).

We estimate time-series regressions for two different dependent variables: production and world market share. The regressions include controls for time trends, real country exchange rates, world resource price (where appropriate), and a dummy variable for the years of the 1980s financial crisis. Our approach exploits the fact that the 1980s financial crisis was a well-defined event in countries that were not in chronic financial crisis. (Countries in chronic crisis would likely have little access to capital markets prior to an international financial crisis, and thus no significant change in problems arising from indebtedness during the 1980s crisis.) In some regressions, we replace the crisis dummy variable with a measure of country indebtedness, which varies to some degree within the crisis time period. In almost all regressions, the financial crisis dummy indicates an economically important and statistically significant change in production and world market share during the 1980s financial crisis. In addition, we also find significant effects in most regressions that utilize a measure of indebtedness instead of the crisis dummy. The output and market share regressions yield very similar results.

While the focus of the paper is Brazil, Chile and Mexico, we also report findings for four other resource producing countries that had decidedly different experiences during the 1980s crisis. For Bolivia and Peru, production of key resources does in fact

accelerate at the start of the 1980s debt crisis; however, production sharply declines following their announcement of a moratorium in debt repayments. We also present findings for Indonesia, a developing country and major exporter of natural resources who did not succumb to the 1980s debt crisis, and thus serves as a useful counterfactual. Regressions for Indonesia's major resources show little or no acceleration of production during the international debt crisis. Finally, the U.S. also serves as a useful counterfactual in that the U.S. clearly did not lose access to world capital markets in the 1980s crisis. Regressions for U.S. output (and market share) of copper, iron ore and silver show a sharp *decline* in production during the 1980s crisis.

In addition to examining an unexplored channel through which financial market crises impact real behavior, our findings have a number of interesting implications. First, our study provides empirical evidence that high debt levels can impact natural resource production; while there is considerable speculation on this issue, there is little empirical evidence that high debt levels matter. Second, our findings provide new insights into why commodity prices are so volatile: countries expanding production to service debt burdens during financial crises likely exacerbate the cyclical patterns of commodity prices. Third, our results highlight a previously unexplored reason for financial contagion. While an individual country may temporarily benefit from expanding resource production to service its debt burden, the negative impact this expansion has on price can initiate a negative feedback cycle. Specifically, other countries, because of a decline in resource revenues, may be compelled to expand their production to service debt, further hampering the ability of all countries that rely on resource revenues to repay their debts. In such an environment, creditors may be better off encouraging countries to not expand production during financial crises in order to avoid financial contagion. A final implication is that countries with large debt burdens and extensive reliance on natural resource revenues should insulate themselves (e.g., hold a buffer stock of liquidity) from both financial crises and the potential accompanying decline in resource prices. Not only would this directly benefit the individual country, but it may also benefit world capital markets, as it would protect against the potential for financial contagion discussed above.

The next section provides an overview of the 1980s financial crisis. Section III briefly describes the channels through which a financial crisis can cause a temporary shift in the supply of mineral production. Section IV discusses the data and provides plots of the key data series. Section V describes the econometric model and Section V reports the main results. Section VII discusses results for additional countries, including Indonesia and the United States. The final section discusses some of the implications of our findings.

II. The 1980s Financial Crisis

A. Brief Overview

The 1980s international financial crisis was largely concentrated in Latin America. The history of the crisis is well documented in many sources, including Cline (1995), Krueger (1987), Kuczynski (1988) and Sachs (1989). Between 1973 and 1982, gross outstanding external debt of Latin America and the Caribbean grew at a compound rate of 25%, which was almost four times the growth rate of gross national product (Kuczynski, 1988, p. 38). One major reason for the rapid increase in debt was the pronounced rise in oil prices in the 1970s, which led to balance of payment problems for oil importing countries such as Brazil and Chile. By 1981, the stock of external debt in Latin America reached the equivalent of three times one year's export earnings. Problematically, roughly 70% of this debt was at floating interest rates (Kuczynski, 1988, p. 73) and most of the debt was denominated in dollars.

Beginning in the late 1970s, a series of negative shocks put considerable pressure on most heavily indebted developing countries. First, the price of oil increased by nearly $20 per barrel between 1979 and 1981. Second, beginning in 1978, international interest rates rose to very high levels, peaking in the early 1980s. The variable rate on most Latin American debt was tied to the London Interbank Offering Rate (LIBOR), which averaged 14.0% in 1980 and 16.7% in 1981. Third, in both 1981 and 1982, the value of the dollar increased markedly against most other currencies. Finally, prices for non-energy primary commodities fell sharply: a weighted index of commodity prices for 33 non-energy commodities fell by nearly 25 percent between the start of 1981 to the end of 1982 (*The World Bank, The Outlook for Primary Commodities*).

On August 12, 1982, Mexico notified the IMF and the U.S. Secretary of Treasury that it was unable to service an $80 billion debt obligation. This event initiated a dramatic reduction in voluntary lending to heavily indebted developing countries. In November of 1982, Brazil announced it was seeking a moratorium on the repayment of principal to commercial banks. By October of 1983, twenty-seven developing countries had rescheduled, or were in the process of rescheduling, some $239 billion of debt, with most of the rescheduling occurring in Latin America. In November of 1982, the IMF put a rescue plan in place for Mexico, which became the precedent for other Latin American countries, including the February 1983 rescue package for Brazil. For Mexico and Brazil, the rescue packages provided an eight-year rescheduling of principal due to commercial banks. Sachs (1989, p. 25) emphasizes that "the rescheduling also provided for *the continued and timely payments of all interest due*." As Kuczynski (1988, p. 87) discusses, the regular payment of interest on the debt was essential for the safety of the major international banks, particularly those in the United States and Britain. From 1983 to 1987, substantial portions of the principal obligations of Brazil, Chile, Mexico and other Latin American countries were rescheduled.

It is widely agreed that beginning in 1989, the Brady Plan set in motion an end to the 1980s financial crisis. The Brady Plan, with the assistance of substantial funds from the IMF and the World Bank, brought about large debt reductions in eighteen nations (Cline, 1995, chapter 5). Beginning in the early 1990s, capital inflows into Latin America increased sharply. From a low of approximately $4 billion in 1988, capital inflows reached nearly $60 billion by 1992 (Cline, Table 8.1). Cline (1995, p. 253) observes that, compared to the decades-long lockout from capital markets for Latin American defaulters in the 1930s, the rapid recovery of capital inflows in the early 1990s was remarkable.

Following the 1980s debt crisis, the next major international financial crisis was the 1997-98 Asian crisis, which was centered in Indonesia, South Korea, Thailand, Hong Kong, Malaysian and the Philippines. While the Asian crisis did have some impact on Latin America, the magnitude was much less than in the 1980s crisis. Fostel and Kaminsky (2007, p. 7) note that Latin America's gross issuance in international markets during the height of the1980s debt crisis "crashed to about 4 percent of the levels attained

in the early 1980s" whereas "total issuance declined only to about 40 percent of is peak in 1997, suggesting a more continuous access to international capital markets" during the Asian crisis. Thus, for Latin America, the Asian financial crisis does not provide a clear-cut example of a loss of access to capital markets, and thus we do not include this crisis in our study.

B. Overview of Mexico, Chile, and Brazil

We briefly summarize some key facts for Mexico, Chile and Brazil, based on information from the World Bank's *World Debt Tables.* One measure of the debt burden (used later in the regressions) is the *Interest Ratio*, which is interest payments divided by GNP, where the interest figure is for public and publicly guaranteed debt. This form of debt typically constituted the vast majority of the total stock of debt in each country during the 1980s financial crisis. We focus on interest payments because, while principal was commonly rescheduled during the financial crisis, debtors were pressured to not default on interest payments.

Mexico's stock of public and publicly-guaranteed debt jumped from $3.9 billion in 1972 to $66.8 billion in 1983. Its *Interest Ratio* rose from 0.020 in 1981 to 0.047 in 1983, and then remained relatively constant until declining sharply in the late 1980s, reaching 0.021 by 1990. In early 1990, Mexico had completed its Brady Plan agreement, reducing its long-term bank debt by approximately 35%. Mexican capital inflows, after being near zero between 1983 and 1989, were over $20 billion in both 1991 and 1992 (Cline, 1995, Table 8.7).

For Chile, pressure by foreign lenders caused Chile's government to guarantee private debts, leading to a nearly three-fold increase in public and publicly-guaranteed debt between 1982 and 1986. Between 1981 and 1984, Chile's *Interest Ratio* rose from 0.016 to 0.053 and remained elevated throughout the crisis. By 1992, however, Chile's *Interest Ratio* had fallen back to levels immediately prior to 1981. Unlike Brazil and Mexico, Chile did not participate (by its choosing) in the Brady Plan. Cline (1995, p. 289) concludes that Chile's debt problems were over by the early 1990s, noting that the problem by then was "too much foreign capital rather than too little."

Brazil's stock of public and publicly-guaranteed debt jumped from $5.9 billion in 1972 to $59.1 billion in 1983. In the early 1980s, Brazil's *Interest Ratio* did not rise as

rapidly as Chile's or Mexico's. Brazil, however, entered a serious recession in the late 1980s and was in arrears on interest payments in 1987, 1989 and 1990. Brazil did not reach a Brady agreement with its banks until July 1992. Net capital inflows to Brazil were negative throughout the second half the 1980s and did not become positive until 1992.

For the analysis that follows, we choose slightly different dates for the end of the 1980s financial crisis, based on differences in each country's experience and the views of experts on the timing of the crisis. We set Mexico's last year of the crisis at 1989 as it had completed its Brady Plan in early 1990 and capital was flowing back to the country by that year. We date the end of the crisis in Chile at 1990, based on the timing of the return of capital flows to this country. We date Brazil's crisis as ending at 1991 because its Brady Plan was delayed to early 1992 and capital inflows finally became positive in 1992. Choosing a common ending year of 1989 or 1990 has little impact on our findings.

III. Financial Crises and Natural Resource Production

The most obvious channel through which a financial crisis may cause an acceleration of mineral production is through an increase in the shadow cost of capital.[6] For an exhaustible resource, the optimal output path involves equating the present value of the marginal unit of production across time periods. From Hotelling's (1931) classic paper on exhaustible resources, the intertemporal condition for optimal production between periods t and t+1 is:

$$P_t - C'(q_t) = \{P_{t+1} - C'(q_{t+1})\}/(1+\phi_t) \qquad (1)$$

where P_t and P_{t+1} are the (expected) world prices of the mineral, $C'(q_t)$ and $C'(q_{t+1})$ are the marginal costs of output (q), and ϕ_t is the shadow cost of capital. Other things equal, an increase in P_t will lead to an expansion in q_t. More importantly, an increase in ϕ_t makes production in period t relatively more valuable compared to production in period $t+1$. During the 1980s financial crisis, for a heavily-indebted country cut off from world capital markets, ϕ_t was surely very high, arguably far above LIBOR. While rising

[6] A review of this literature can be found in Hartwick and Olewiler (1986, chapter 3), including a discussion of the impact of higher interest rates on exhaustion of resources.

marginal costs of production will attenuate increases in production in period *t*, history shows that large increases in mineral production can quickly be achieved through additional labor inputs (see footnote five in the introduction). Thus, a large increase in the shadow cost of capital could have caused substantial increases in production for some countries during the 1980s financial crisis.

There is a second channel through which a financial crisis can accelerate resource production. Governments face a budget constraint that likely varies in the degree of tightness. (Firms may also face budget constraints if they have imperfect access to financial markets.) The government budget constraint likely becomes much tighter for countries significantly affected by a financial crisis, particularly if a country is close to defaulting on its debt. For the purposes of discussion, consider the following simplistic government budget constraint:

$$NewBorrowing_t + ResourceEarnings(P_t, q_t) \geq Interest(r_t) + CurrentPublicDeficit_t \qquad (2)$$

$ResourceEarnings(P_t, q_t)$ depend on both the world resource price and country specific output. $Interest(r_t)$ is the government's interest on public debt, which depends on the current LIBOR rate. The $CurrentPublicDeficit_t$ should be thought of as current government outlays less all revenues *except* the revenues derived from the sale of natural resources. One can also view equation (2), suitably modified, as applying to a private firm.

At the start of the 1980s, a series of events almost surely sharply tightened the government budget constraint in the countries we study. The large increase in LIBOR rates temporarily increased $Interest(r_t)$. Another event, first impacting Brazil and Chile, and later Mexico, was the sharp decline in prices of key resource exports (likely accentuated by country's attempts to stave off default). Finally, and perhaps most importantly, voluntary international private lending ceased soon after the start of the 1980s financial crisis, greatly curtailing new borrowing. This loss of access to world capital markets was of major importance, as many countries were financing most of current debt service through new borrowing. If the constraint became sufficiently tight because of these events, governments would have presumably found it increasingly

difficult to pay current interest, which appears to describe the situation of Brazil, Chile and Mexico during parts of the 1980s financial crisis.

The loss of access to new borrowing during a financial crisis could cause a country that was initially on the optimal path of resource production given by the Hotelling condition (equation (1)) to temporarily accelerate resource production, since current period production is suddenly more valuable if it allows the country to alleviate the budget constraint and avoid the high costs associated with default.[7] It is not automatic, however, that such a country can increase resource earnings by expanding current period production. In particular, one country's increase in production could cause a sufficiently large fall in price that resource revenues decline; this is most plausible for a country with a very large world market share. Consider, however, a country with a world market of share of 15%, similar to many cases in our study. If such a country expands its output by 10%, and no other countries change their output, *world output* expands by only 1.5%. This expansion will lower the world resource price (% change in world output/world demand elasticity), but not by a sufficiently large amount to reduce resource revenues flowing to the country in question unless the world demand elasticity is very small (e.g., less than 0.15 in absolute value).

The above discussion abstracts from strategic considerations. If an expansion by one country elicits a proportionate expansion by other important resource producers, then it is quite plausible that revenues (and therefore resource earnings) will fall for all countries, including the country initiating the expansion. On the other hand, if other countries respond to the initial expansion by contracting their production, then the country expanding production would almost surely earn higher revenues in the short-run. It is beyond the scope of this paper to explore strategic interactions between resource producing countries (and we are aware of no research on this topic). We point out, however, that major resource producers such as the United States and other developed countries did sharply contract their production during the 1980s financial crisis, making it more plausible that a country facing a tightened budget constraint during a financial crisis could earn higher resource revenues by expanding production.

[7] Of course, cutting the budget deficit is another option, and the Brazilian and Mexican governments did make large adjustments to the deficit, principally by slashing government expenditures. Such cuts in expenditures, however, are politically costly.

A number of studies explore the linkages between financial structure and output decisions at the firm and industry levels. For example, a classic paper by Brander and Lewis (1986) shows how financial structure can be used as a commitment device: under limited liability, as firms become more leveraged, they have an incentive to expand production. Empirical studies evaluating the potential for the Brander and Lewis effect have generally found that increases in leverage at the firm and industry level are associated with softer product market competition (see, e.g., Kovenock and Phillips, 1995 and 1997; Chevalier, 1995). In contrast, our findings on resource production at the country level are broadly consistent with some of the main theoretical points in Brander and Lewis (1986). A potential reason that our findings differ from prior studies is that developing countries face more severe penalties from default (e.g., loss of access to future trade) than the penalties facing the managers (and owners) of the typical leveraged U.S. firm, perhaps causing indebted countries to take more aggressive measures during periods of severe financial distress. We also note that the setting we consider – the loss of access to capital markets for heavily indebted governments – differs somewhat from the scenario in Brander and Lewis (1986) where indebted firms have limited liability and perfect access to financial markets in all periods.

To summarize, equations (1) and (2) illustrate two different channels through which a financial crisis may impact resource production: i) an increase in the shadow cost of capital, and ii) a tightening of the budget constraint. As a side note, we point out that while both channels are consistent with a financial crisis increasing resource production, the two channels have potentially conflicting predictions about the impact that *price changes* have on resource extraction. In equation (1), a temporary decline in price should always lead to a decline in production, which is the standard prediction in economic theory. In contrast, equation (2) suggests that, all else equal, if the budget constraint is binding, then a decline in price can in some circumstances lead to an expansion of production. The difference in predictions is due to the fact that standard models of resource extraction do not allow for binding budget constraints. We also note that equations (1) and (2) appear for the sake of discussion and not for estimation purposes. In particular, the Hotelling theory of exhaustible resources has proven difficult to test, as

the models are inherently dynamic, involving expectations on future price and anticipatory behavior.[8]

To our knowledge, no previous studies have considered the impact of financial market crises on resource production.[9] Empirically evaluating the impact of a financial crisis on resource production faces several difficulties. While countries vary a great deal in their level of indebtedness, a study focusing on *cross-sectional* variation would face several criticisms, including heterogeneity across countries arising from differences in institutions, ownership structure, resource endowments and "debt tolerance." A broad panel study that focuses on within country variation *across time* also faces challenges. In particular, in recent decades, many developing countries are in a situation of "chronic crisis" (e.g., Sachs, 2002); for these countries, an international financial crisis may lead to no meaningful time-series variation because of chronic lack of access to world capital markets. Our approach is to focus on the 1980s debt crisis because it is a pronounced yet well-defined event and to focus on countries which were not in chronic financial crisis.

IV. Resource Producers, Output, and Prices: Plots and Summary Statistics

We examine the time period 1973-1996, a choice which reflects both data availability and the change in international financial conditions starting in 1997. First, our main data source, various issues of the United States Geological Survey (USGS), does not begin reporting data for CODELCO until 1973 and CVRD until 1974. Second, there was extensive privatization beginning in the mid 1990s, including CVRD, which was privatized in 1997. Finally, the Asian financial crisis began in 1997, which clearly had an impact in Latin America; however, the exact magnitude of this impact is not readily measurable, unlike the virtual total loss of access to international capital markets in the 1980s. Thus, we end our study before the start of the Asian financial crisis.

[8] Chermak and Patrick (2001) review much of the empirical literature and state that "little empirical indication of support for the theory of exhaustible resources has been found, leaving unresolved the question of the theory's usefulness in describing and predicting the behavior of exhaustible resource producers." Moreover, we do not have adequate data -- in particular we do not have production costs -- to consider models based on Hotelling's theory of exhaustible resources.

[9] An even broader topic is the impact of high indebtedness on the environment. Pearce et. al. (1995) provides a review of the literature on debt and the environment and notes that with the exception of some limited evidence on debt and deforestation, the impact of debt on the depletion of resources has not been tested.

For each country, we select major minerals where the country was both the leading producer in Latin America and a leading producer in the world, during the time of our study. For Brazil, the minerals are iron ore, manganese, and tin. For Chile, the mineral is copper.[10] For Mexico, the mineral is silver. In addition to these five minerals, we also examine oil because of its importance to the governments of both Brazil and Mexico. As discussed below, in four of the above seven cases we have production figures at the state-owned enterprise level; in the remaining cases, a state-owned enterprise is not the primary producer of the resource. In these situations, however, we do know the identity of the key producers, which were typically a mix of state-owned and private domestic firms. We begin with a brief overview of the price series for each of these minerals. We then discuss facts about the identity of the producers and present plots of production and world market share. Finally, we present information on world market shares before, during, and after the 1980s financial crisis. Price and output data are hand collected from annual issues of the USGS.[11]

A. Output Prices

We deflate prices with the world Manufactures Unit Value Index (MUV) reported by the IMF. The MUV deflator is based more heavily on goods actually being traded than is the U.S. GDP deflator.[12] Price plots for oil and silver (the two most volatile series) appear in Figure 1A and prices for the other major minerals appear in Figure 1B. For the plots we normalize the price of each mineral at a value of 100 in 1972. Figure 1A shows that oil prices, after rising dramatically prior to the financial crisis, fell sharply in 1986, while silver prices fell precipitously throughout the crisis. Figure 1B shows that tin prices fell sharply throughout the crisis. The price of iron ore and copper fell sharply through most of the crisis, with some recovery near the end of the crisis. Manganese exhibits a mild price decline during much of the crisis followed by a sharp spike at the end of the crisis. The key conclusion that emerges from the price plots is that it is

[10] Silver is another relatively important mineral for Chile, but most of the silver production is a by-product of copper production.
[11] Two years of CVRD data, 1983 and 1984, were not available in the USGS annual reports. We contacted the USGS and they kindly provided the figures for these years.
[12] All of our findings and conclusions are similar if we use the GDP deflator instead of the MUV deflator.

difficult to explain an acceleration of mineral production during the financial crisis as movement along an upward sloping supply schedule.

B. Real Country Exchange Rates

In addition to price, we also include each country's real exchange rate as a control variable in the regressions that follow.[13] The logic is that crises are often associated with a substantial real depreciation in a country's currency, which may bring about a shift from nontradable to tradable goods. Thus, mineral producers, even in the face of stagnant or slightly falling mineral prices, may choose to expand production because of a substantially lower cost of hiring domestic inputs. Indeed, there are declines in the real exchange rate during the 1980s financial crisis in the three countries we study. There are, however, also other periods of sharp declines in exchange rates, including the 1970s and the 1990s, with little movement in production.

C. Identity of Producers and the Output Series

We provide a few facts concerning the identity of the producers and the economic importance of each natural resource. Plots of mineral and oil production appear in Figures 2A-2G. The units of output are metric tons (and in some cases thousands or millions of metric tons) for minerals and thousands of barrels for oil (see the bottom of each figure). The plots indicate that in most cases, production and market share jumped substantially shortly after the start of the financial crisis and then sharply declined near the end of the crisis. While the initial jumps in production could potentially just be a coincidence (such as the simultaneous opening of new mines), the combination of jumps in production shortly after the start of the crisis followed by sharp declines in production near the end of the crisis is difficult to rationalize with explanations that do not depend on the financial crisis. In addition, the jumps in production of natural resources stand in sharp contrast to the declines in GDP in the three countries during much of the 1980s crisis.

C.1. Iron Ore: CVRD

In 1981 (the eve of the financial crisis), iron ore accounted for more than half of the value of all minerals produced in Brazil and accounted for approximately 8% of

[13] The real country exchange rate comes from the USDA (www.ers.usda.gov/data/ExchangeRates/).

Brazil's export earnings (USGS, 1981). Brazil was the world's leading exporter of iron ore (USGS, 1981) and the state-owned company Companhia Vale do Rio Doce (CVRD) was the world's leading producer of iron ore. CVRD had long been one of Brazil's leading earners of foreign exchange and CRVD often earned very high returns on assets. Figure 2A shows that in 1984, CVRD's production and market share rose sharply relative to the level (and trend) of production in the late 1970s and early 1980s. Production in 1984 was 31% higher than the previous year and market share was 16% larger. CVRD's production continued to increase substantially during the remainder of the crisis, but declined sharply immediately following the end of Brazil's financial crisis.

C.2. Copper: CODELCO

In 1981, Chile accounted for most of the copper produced in Latin America and the state-owned Corporación Nacional del Cobre de Chile (CODELCO) was the world's largest producer of copper, accounting for approximately 80% of Chile's copper production in the 1970s and 1980s. CODELCO had the lowest average cost of production of the world's major copper producers (USGS, 1983). At the start of the crisis, CODELCO generated more than 40% of Chile's foreign exchange (USGS, 1984, p. 187) and was the government's main source of revenue.[14] Figure 2B shows that CODELCO substantially increased both its production (by 15.6%) and its world market share (17.3%) in 1982, the start of the crisis. Production peaked in 1989 at a level 39.1% above the 1981 figure, and world market share peaked in 1986 at a level 26.0% above the 1981 level. CODELCO's output, and especially its market share, fell substantially after 1989.

C.3. Oil: PEMEX

In 1981, Mexico was the leading producer of oil in Latin American. All oil production came from the state-owned company Petroleos Mexicanos (PEMEX). Much of the public sector debt in Mexico was in the PEMEX name (Kuczynski, 1988, p. 63). The Mexican government in the 1980s and 1990s was heavily dependent on revenues from PEMEX. For example, in the early 1990s, 70% of Mexico's foreign exchange and

[14] For example, in 1983, CODELCO earned a net income of $220.6 million, paid taxes of $678.5 million (in 1983 dollars) and provided Chile with 46% of its foreign exchange. In 1989, taxes and dividends transferred to the state comprised 30% of the government's revenues (International Directory of Company Histories, Volume 40, p. 122).

approximately 45% of the government's tax receipts came from PEMEX, and these revenues were claimed to have been critical for Mexico's repayment of its debt burden.[15] Between 1979 and 1982, PEMEX (Figure 2C) greatly expanded production and world market share. During the financial crisis, production and world market share remained roughly triple the levels of 1977-1978. No doubt much of the increase in production was due to the dramatic increase in oil prices in the late 1970s and early 1980s. During the crisis, however, there is no corresponding output decline in response to the more than 50% decline in oil prices in 1986.

C.4. Oil: PETROBRAS

In 1981, Brazil was the third largest producer of oil in Latin America and the value of oil production exceeded the value of Brazil's iron ore production. All oil production came from the state-owned oil company Petroleo Brasileiro (PETROBRAS). There are claims that during the 1980s, PETROBRAS was used as an instrument in an attempt to pull the country out of its debt problem (e.g., International Directory of Company Histories, Volume IV, 1991, p. 503). In 1981, Brazil's import bill for oil was approximately $10 billion, amounting to nearly half its total import bill (USGS, 1981). Between 1981 and 1987, PETROBRAS (Figure 2D) increased its oil production and world market share by approximately 300%. Similar to PEMEX, there was no decline in oil production in the late 1980s in response to the fall in oil prices. The sharp increase in oil production was accompanied by a nearly offsetting decline in barrels of imported oil (USGS, 1981-1986), which saved the Brazilian economy (and the government, which controlled much of the economy through state-owned enterprises) billions of dollars during the financial crisis.

C.5. Tin: Brazil

In 1981, the main tin producer in Brazil was Paranapanema S.A. Mineracao, which in the late 1980s became the world's largest tin producing company. While a private company, most of Paranapanema's stock was closely owned by a group of state-owned company pension funds led by Previ, the pension fund of state-controlled Bano do

[15] In the 1990s, PEMEX paid a tax of 18% on total revenues from oil and gas and a 50% corporate profits tax. In addition, PEMEX, as a decentralized public agency of the Mexican government, turned over most of its profits to the Mexican government (International Directory of Company Histories, 1998, Volume 19, pp. 297).

Brasil. During the late 1980s, a substantial fraction of Brazil's tin production came from the garimpeiros, prospectors who mined tin on land for which Paranapanema owned the exploration license and who were required the sell their output to Paranapanema (USGS, 1988). Between 1982 and 1988, Brazil's production of tin (Figure 2E) increased by approximately 370% and its world market share increased from 4.0% to 21.8%. The acceleration was due to large increases in production both by Paranapanema and the garimpeiros.[16] By 1988, Brazil was the world's leading producer of tin, a position it held through 1990. In the early 1990s, Brazil's tin production collapsed and its world market share fell by more than 50%.

C.6. Manganese: Brazil

In 1981, Brazil was the world's third largest producer of manganese, with a market share of nearly ten percent. The market value of manganese output, however, was more than an order of magnitude smaller than the value of Brazil's iron ore or petroleum production. The largest producer was Industria E Comercio De Minerios S.A., which was a joint venture of Cia. Auxiliar de Empresas and Bethlehem Steel of the United States. Because of the connection with Bethlehem Steel, manganese is the least obvious mineral to include in the study. As shown in Figure 2F, Brazil's manganese production peaked during the financial crisis (1984-1986); production declines, however, before the crisis ended.

C.7. Silver: Mexico

At the start of the 1980s crisis, Mexico was the world's leading producer of silver, and silver accounted for roughly 50% of the value of mineral exports, not including oil (USGS, 1982, p. 631). The Mexican government had extensive equity participation in many of the leading silver producers. Comision de Fomento Minero, a large government agency, was involved in mineral operations of many companies and had equity ownership in several silver producers, including Mexico's largest silver mine (USGS, 1985, pp. 580). Mexico's largest silver producer, Industrias Penoles, was heavily indebted at the start of the financial crisis and its profits fell sharply in the early 1980s

[16] The USGS reports sporadic figures for the production of Paranapanema and the garimpeiros. Both Paranapanema and the garimpeiros greatly increased production in the late 1980s and then sharply curtailed production in the early 1990s. The USGS reports the following tonnage for Paranapeanema for the years 1984, 1988, 1989, 1992, 1994, and 1995: 12,780, 18,000, 16,500, 14,853, 9,300 and 10,150, respectively.

because of the fall in the price of silver.[17] Mexico's silver production (Figure 2G) rose rapidly in the period 1982-1984, reaching a level 42.4% above the 1981 figure. Production and world market share remained at a high and near constant rate from 1984-1988. Beginning in 1989, production and world market share fell sharply, and production figures in the early 1990s had returned to levels similar to those at the start of the crisis.

V. Empirical Specification

We estimate a simple regression (with 24 annual observations between 1973 and 1996) to examine whether there was a statistically significant change in production and world market share during the financial crisis after controlling for long-run trends, world prices (where appropriate), and real country exchange rates. One baseline specification is the log-linear model:

$$\ln q_t = \beta_0 + \beta_1 t + \beta_2 \ln P_{t-1} + \beta_3 \ln ExchRate_{t-1} + \beta_4 CrisisDummy + \varepsilon_t, \qquad (3)$$

where q_t is the quantity of a particular mineral in period t (see Figures 2A-2G) and β_0 is the firm- (or country-) specific intercept. β_1 is the coefficient on the time trend and the plots of production indicate that there are positive trends in production, as expected if a country is at a point in its history where new reserves are being developed. β_2 reflects the impact of the lagged deflated world price (P_{t-1}) on output; as discussed in Section II, the expected impact of world price is ambiguous. β_3 measures the exchange rate effect, which is expected to be positive. *CrisisDummy* is a dummy variable that takes the value of one during the 1980s financial crisis and zero otherwise. The crisis dummy can be thought of as capturing the temporary supply shift due to either the sharp increase in the shadow cost of capital or because of the tightening of the government budget constraint during the 1980s crisis. For ease of notation, equation (3) has no subscript for individual minerals.

We also estimate a similar specification with (log) market share as the dependent variable instead of output. The regression is the same as equation (3) except we drop

[17] In 1983, Industrias Penoles had foreign debt of $208 million dollars; in the same year, net profits were only $10.5 million, down from $78.6 million in 1980, due to the sharp decline in silver prices (International Directory of Company Histories, Volume 22, p. 285). In addition, much of Penoles' debt was at floating rates.

price, since the dependent variable is market share and price is common to all countries. Two important aspects of the market share specification are that it is immune from any concerns about shifts in world market demand and it does not require price in the specification. For these reasons, the market share regression is our preferred specification.

The dummy variable approach is common practice in evaluating the impact of a natural experiment.[18] While we view equation (3), together with its market share counterpart, as the key regressions, we also report the results of a different approach to capturing the financial crisis. In an effort to capture possible *variation* in the intensity of the crisis, we replace *CrisisDummy* with the natural log of the one-period lag of the *Interest Ratio* (which we abbreviate by Int Ratio$_{-1}$ in the regression tables). As discussed in Section II.B, the *Interest Ratio* is the ratio of public interest payments to GNP, a commonly used measure of the debt burden.[19]

We considered the possibility of a unit root in the production series. Care must be taken since the 1980s financial crisis likely created a major structural break in the data. As argued by Perron (1989, p. 1370), if the break in the data is large, "one could hardly reject the unit root hypothesis even if the series is that of a trend (albeit with a break) with i.i.d. disturbances." The presence of a structural break will bias conventional unit root tests toward the nonrejection of a unit root. We follow the procedure suggested by Perron (1989) and estimate the regression $q_t = \alpha q_{t-1} + \varepsilon_t$ where q_t are the residuals of the production series after allowing for a both a trend as well as *CrisisDummy* to capture the structural shift. That is, we find the residuals from a regression given by equation (3), but without the price and exchange rate variables, and then regress these residuals on the lagged residuals. Most of the estimated α coefficients are much closer to zero than to one.[20]

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[18] We set the *CrisisDummy* equal to one as follows: Mexico, 1982-1989; Chile, 1982-1990; and Brazil, 1982-1991. As discussed in Section II, Mexico was the first country to negotiate a Brady agreement and it experienced significant positive flows of capital by 1990; Brazil's agreement was considerably later and positive capital flows were delayed until 1992.

[19] Brazil was in arrears on its interest payments in the late 1980s. We add the change in stock of arrears to actual interest payments to obtain the interest payments owned in a particular year.

[20] Following the same order of minerals as appears in Table 1, the α coefficients and standards errors for the output series are: 0.192 (.214); 0.249 (.211); 0.720 (.126); 0.609 (.166); 0.231 (.210); 0.527 (.186); and 0.300 (.201). The α coefficients are well below one in all cases and typically much smaller than

Durbin-Watson and Godfrey's serial correlation tests indicate the presence of first-order, and in some cases, second-order serial correlation in all regressions (AR order appears in the last column in each table of regression results). We use the Yule-Walker correction (which is equivalent to the Prais-Winsten correction in the case of an AR(1)).[21] The reported R-squared is the value for the regression after transforming for autocorrelation.

VI. Regression Results

A. Output Regressions

Table 1 presents the output regression results. The table begins with the findings for the four state-owned companies, CODELCO (copper), CVRD (iron ore), PEMEX (oil) and PETROBRAS (oil) and then reports the results for manganese and tin in Brazil and silver in Mexico. There are a total of fourteen regressions, or two regressions for each of the seven production series that appear in Figures 2A-2G. In each set, the first regression is the specification given by equation (3) and the second regression replaces the crisis dummy with the natural log of the lagged interest ratio (Int Ratio$_{-1}$).

The price coefficients are generally insignificant, with large positive and statistically significant price effects only in the PEMEX regressions. Based on the price and output plots, this finding is not surprising. For one thing, prices during the financial crisis were relatively low compared to prices during the full sample period. In addition, for periods of very high mineral prices (e.g., tin in the late 1970s and early 1980s, manganese in the late 1980s and early 1990s), there is no associated movement in output. The one exception is PEMEX, where high oil prices in the late 1970s and early 1980s lines up with PEMEX's sharp increase in production. Price is negative in seven of the regressions, but the coefficients are typically fairly small and only statistically significant (at the 10% level) in the second tin regression. In contrast, the coefficients for the

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coefficients in the examples in Perron (1989) where a unit root can be rejected at a 5% confidence level. The small size of our sample, however, leads to large standard errors. We can reject the null of a unit root at the 5% to 10% level in most, but not all, cases. The estimates of α and its standard error for the market share series are very close to the estimates for the output series.

[21] The Yule-Walker method estimates the autoregressive form of the error term and then estimates the coefficients via generalized least squares. The Cochrane-Orcutt method is similar to the Yule-Walker method for first-order autocorrelation, except the Yule-Walker method retains the first observation.

exchange rate variable are generally positive and are statistically significant in five of the regressions.

The coefficient for the financial crisis dummy is positive in all regressions and statistically significant in six of the seven regressions. The crisis dummy is not statistically significant in the manganese regression, apparently due in part to the high volatility of production evident in Figure 2F. The magnitudes of the coefficient estimates on the crisis dummy are generally similar in all but one regression, and the estimates suggest an economically important increase in production of ten to twenty percent, relative to trend, during the crisis period. The one outlier is the very high coefficient in the tin regression, consistent with the enormous increase in Brazil's tin production during the financial crisis.[22]

In the second set of regressions, coefficients for the interest ratio (Int Ratio$_{-1}$) are similar to those for the crisis dummy. The interest ratio coefficients are positive in all seven regressions and are statistically significant in five regressions. In general, there is little difference between the crisis dummy regressions and the interest ratio regressions.

B. Market Share Regressions

Table 2 reports regressions where world market share is the dependent variable. Recall that Figures 2A-2G show that plots of world market share and output are similar. These plots, together with the fact that price is generally not significant in Table 1, suggest that the coefficients for the key variables in the market share regressions should be roughly similar to those in the output regressions. Consider first the regressions where the key variable is the crisis dummy, the specification we believe best captures the impact of the 1980s financial crisis on resource use. The crisis dummy is statistically significant in six of the seven regressions. The one exception is manganese, where the crisis dummy is positive but not statistically significant. Overall, the point estimates for the crisis dummy variable in the market share regression are similar to their counterparts in the output regressions.

[22] Tin is the one case where trend squared enters the regression with a large, statistically significant coefficient (negative). When trend squared is included in the tin regression, the coefficient for the crisis dummy is 0.686 with a standard error of 0.114. For the tin regression where the interest ratio replaces the crisis dummy, the estimated coefficient for the interest ratio is 0.601 with a standard error of 0.329.

When the lagged interest ratio is used in place of the crisis dummy, the coefficients are positive and significant in five of the seven regressions (CVRD, CODELCO, PEMEX, tin and silver). One noteworthy difference between this version of the market share and the output regressions is tin, where the point estimate for the lagged interest ratio is 0.282, half of the magnitude of the point estimate in the corresponding output regression. The reason for the lower point estimate for the interest ratio in the market share regression is that Brazil's world market share of tin falls off more slowly than its actual production. Thus, by the early 1990s, when Brazil's interest ratio is relatively low, its world market share is still relatively high. We prefer the crisis dummy variable over the interest ratio, which we do not think proxies the financial crisis for Brazil as well as the simple crisis dummy.[23]

C. Robustness and Alternative Specifications

We considered a variety of alternative specifications, beginning with alternative timing of the price variable. Recall that price is lagged one period in the main specification and that the price coefficients are positive and statistically significant only for the PEMEX regressions in Table 1. We re-ran all regressions with price lagged two periods, as well as with contemporaneous price. In addition, we ran all regressions with nominal price (i.e., price not deflated by the IMF's MUV deflator) and with price deflated with the GDP deflator instead of the MUV deflator. For all of these additional regressions, price is statistically significant only for the PEMEX regressions, the point estimates for the key variables change very little, and the patterns of statistical significance remain.[24] Finally, we dropped the price variable from all output regressions and found little change in the key results. Finding little or no price effect for mineral production is likely due in large part to the fact that mineral prices are so highly volatile that producers may place little weight on recent prices when making current production

[23] For one thing, the interest ratio can vary a great deal over time because of fluctuations in measured GNP, rather that fluctuations in the amount of interest owed. In addition, Brazil was still facing major problems in 1990 and 1991, despite the decline in the interest ratio.

[24] We also interacted price with the crisis dummy. The idea is that price may have a positive impact on quantity supplied during years where there is not a debt crisis and a negative impact during the debt crisis, as discussed in the second section. In no regressions did the price coefficient become significant because of the addition of the interaction effect.

decisions. The lack of a price effect may also be due to the ambiguous prediction for price (discussed in Section III).

We also dropped the exchange rate from all regressions and the estimated impact of the financial crisis was either stronger or unchanged. Lagging the interest ratio by two periods instead of one has little impact on the findings. We also examined a different start date (1983 instead of 1982) as well as a common final year for the crisis for all three countries (either 1989 or 1990), and again the main findings for the crisis dummy and interest ratio variable remain unchanged in terms of magnitude and statistical significance.

VII. Other Countries

A. Bolivia and Peru: Debt Moratoriums in the 1980s

Despite being in a state of "chronic crisis" (Sachs, 2002), Bolivia is an interesting case to consider because it took a very different approach to the 1980s financial crisis. Morales and Sachs (1990, p. 159) note that "in the first half of the 1980s, Bolivia experienced an economic crisis of extraordinary proportions." Bolivia's financial crisis began earlier than other countries and Bolivia was in arrears on interest payments in 1980. Bolivia continued to be in arrears in the early 1980s but made extensive debt payments between 1980-1984. However, in May 1984 Bolivia declared a moratorium on repayments of debt to commercial banks. Morales and Sachs (1990, p. 174) note that following the moratorium, Bolivia "maintained a *total suspension* (their italics) of interest payments on its commercial bank debt." Morales and Sachs (1990, p. 174) describe how the commercial banks ultimately agreed to permit Bolivia to buy back its debt on the secondary market (around 11 cents on the dollar) as long as Bolivia purchased the debt with funds donated by foreign governments. (Bolivia was the first country in which the U.S. government supported a policy of debt relief.) As expected, starting in 1985, the *World Debt tables* show a dramatic plunge in Bolivia's interest payments.

In view of Bolivia's moratorium on debt service to commercial banks beginning in 1984, it is interesting to consider Bolivia's pattern of natural resource production. In 1980, the export of minerals and fuels – mainly tin and natural gas – provided Bolivia with 86 percent of its foreign earnings and most of the government's revenues. Bolivia

was the world's third largest producer of tin in 1980. Tin production rose from 27,648 metric tons in 1979 to 29,830 metric tons in 1981 and remained high in 1982 and 1983, but then fell to 19,911 metric tons in 1984 and averaged only 11,405 metric tons between 1985-1988. Natural gas production also initially increased – from 159,961 to 188,198 million cubic feet between 1979 and 1982. Production then fell substantially in 1984 and averaged 164,012 million cubic feet over 1985-1988. One interpretation of this production pattern is that Bolivia initially attempted to service its debt burden by expanding resource production; but once Bolivia declared a moratorium, added production was no longer needed given the sharp decline in the required debt service.

Peru also declared a moratorium on debt repayments, but the moratorium was *partial,* and thus Peru is not as clean a case as Bolivia. Peru was experiencing significant debt difficulties as early as 1976 (Sachs, 1990, p.16), well before the start of the 1980s debt crisis and was in arrears on interest payments early in the debt crisis. After taking office in 1985, President Alan Garcia declared a partial moratorium on debt: Peru would pay commercial banks no more than 10% of its export earnings.[25] Output of key resources (e.g., silver) did accelerate in the early and mid 1980s, but then declined after the start of the debt moratorium.[26]

B. Indonesia

At the time of the 1980s debt crisis, Indonesia was by far the largest economy in Asia that focused on natural resource production. There are four main reasons why Indonesia is a useful counterfactual. First, like the countries we examine in Latin America, Indonesia was a developing country earning most of its foreign exchange from the export of a few key natural resources. Second, prior to the start of the 1980s crisis, Indonesia was actively accessing international capital markets. Third, Indonesia was substantially indebted at the start of the debt crisis (although not as indebted as many Latin American countries; see Sachs, 1990, p. 6). Finally, and most importantly,

[25] The partial moratorium appears to have made a major difference in Peru's debt service: the *World Debt Tables* show that interest payments fall sharply in the late 1980s and interest in arrears jump to nearly $3 billion in 1988 (17 percent of GDP).

[26] Peru was the world's second leading silver producer. Silver production, which was nearly constant in the 1970s, peaked in 1987 at a value 68% greater than the start of the 1980s. Production then fell substantially for the next six years.

Indonesia did not succumb to the 1980s debt crisis: it was not forced to reschedule its debt or participate in the Brady Plan and it retained good access to international capital markets (Cline, 1995).

At the start of the 1980s debt crisis, Indonesia was the world's leading producer and exporter of LNG, the second largest producer of tin and the fifth largest producer of nickel. Oil was also a major export.[27] Plots (available on request) of these four resources show no acceleration of production during the 1980s debt crisis. Regressions (based on equation 3) for each of the four resources (for both quantity and world market share) appear in the first half of Table 3. (The market share regressions for LNG are not presented because of lack of data for world output of LNG.) The point estimates for the crisis dummy are small (negative in four cases) in all seven regressions. Furthermore, the only point estimates that are statistically significant are for oil, but these estimates indicate a *decline* in production during the crisis. Thus, there is no evidence that Indonesia accelerated production of its major natural resources during the 1980s debt crisis, consistent with the fact that Indonesia did not lose access to international capital markets during this time period.

C. United States

It is also useful to examine the United States, a developed country which clearly did not suffer loss of access to international capital markets during the 1980s financial crisis. In 1981, the U.S. was the world's leading producer of copper (19.7%), the world's fourth leading producer of silver (11.3%), and the world's fourth leading producer of iron ore (8.7%). The U.S. was a net importer of all three minerals. We ignore tin and manganese because the United States produced very little of those minerals. In the United States, copper and iron ore production were depressed between 1982 and 1987, with copper production averaging only 74.4% of the 1981 level and iron ore production averaging only 58.9% of the 1981 level. By 1990, at the end of the financial crisis, copper production rebounded to 1981 levels and iron ore production was back to 76.0% of the 1981 level. U.S. silver production also fell during the crisis, once silver prices collapsed. It is interesting that while domestic production of minerals declined in the U.S. during the crisis, there was a substantial *increase* in the quantity of copper and silver

[27] Indonesia was a member of OPEC and thus oil production may have been constrained by agreement.

imports during the 1980s financial crisis, as might be expected if there were positive supply shifts in other countries such as Chile and Mexico.

We estimated output and market share regressions for U.S. copper, iron ore and silver production and the results appear in the lower half of Table 3. The coefficient for the crisis dummy is *negative* in all six regressions and statistically significant in five cases. Thus, contrary to the findings for the countries experiencing a crisis, U.S. output and world market share of copper, iron ore and silver *fell*, after controlling for trend and price, during the 1980s financial crisis.

VII. Implications and Conclusions

Our paper provides evidence on the possible connection between the 1980s debt crisis and resource production in key countries. We considered mineral production in Brazil, Chile and Mexico, countries which experienced a serious financial crisis in the 1980s but were not in chronic crisis. We focused on minerals where the country was a leading producer in Latin America and typically a significant world producer. Production and world-market share of tin in Brazil and silver in Mexico increased sharply during the 1980s financial crisis and then declined sharply at the conclusion of the crisis. The movements are particularly dramatic for tin production in Brazil, where market share increased four fold and then fell by fifty percent. Copper (CODELCO in Chile) and iron ore (CVRD in Brazil) production and world market share also jumped shortly after the start of the financial crisis, remained above trend during the crisis, and fell sharply at the end of the crisis. The combination of sharp jumps in the production shortly after the start of the crisis followed by sharp declines in the output near the end of the crisis are difficult to rationalize without an explanation focused on the financial crisis itself. Regressions controlling for trend, price, and the real country exchange rate indicate that there was an economically and statistically significant shift in both production and world market share during the financial crisis for all resources we examine with the possible exception of manganese.

Our findings have a number of implications. While the focus of our study is a *temporary* financial crisis, our results do provide insights on resource use in countries with chronically high debt levels. Some economists (e.g., Tietenberg, 1996, p. 258)

claim that high debt levels have led to an overuse of natural resources, but there appears to be almost no empirical evidence linking debt levels with resource use.[28] Our results suggest that high debt levels can impact resource usage.

Our findings also provide new insights into why commodity prices are so volatile: part of the sharp movement in prices may be due to some countries expanding production in an attempt to service debt during a financial crisis. Given the low demand elasticity of commodities, even relatively modest supply increases (and decreases after the crisis ends) can lead to large movements in prices. Our findings also help explain why many mineral prices dropped sharply in the early 1980s and then remained depressed throughout the decade. That prices remained depressed for so long has "baffled observers" (Kuczynski, 1988, p. 140). Our findings suggest that a temporary rightward supply shift caused by the 1980s international financial crisis can explain part of the decline in prices.

Our results also highlight a previously unexplored reason for financial contagion. While an individual country may benefit (at least temporarily) from expanding resource production to service its debt burden during a financial crisis, this action can have negative spillovers for other countries. One example is Brazil's dramatic increase in tin production, which surely negatively impacted the price of tin (see Figure 1B), putting pressure on other developing countries (e.g., Bolivia) who relieved heavily on tin for export revenues. Initial production expansions in one country can drive down resource revenues for other countries, who may then find it necessary to increase their own production, further amplifying the negative feedback cycle. The end result may be that virtually all countries (and creditors) are better off if no countries increase production during a financial crisis. Creditors may therefore want to encourage countries not to accelerate production in order to avoid financial contagion.

A final implication of our study is that countries with large debt burdens and extensive reliance on resource revenues should insulate themselves (at least partially) from both financial crises and the possible collapse of resource prices. Relying entirely on accelerated resource production to meet debt obligations in times of a financial crisis is surely a suboptimal strategy. One alternative is to build a buffer stock of liquidity, as

[28] For example, Pearce et al. (1995, p. 52) provides a review of the literature on debt and the environment and states: "there is scant empirical evidence to suggest that the connection between debt and the environment is significant."

done by Chile's government since 1989: whenever copper prices are presumed to be above average, some earnings from CODELCO are placed in a stabilization fund. As of early 2009, the stabilization fund equaled approximately $25 billion (14% of Chile's GDP), which has allowed Chile to weather the recent declines in copper prices and to undertake extensive fiscal stimulus in the face of the global recession.[29] Caballero (2003, p. 33) argues that rather than countries self-insuring with costly accumulations of stabilization funds, "emerging markets should be endowed with instruments of hedging and insurance against the disastrous events associated with capital flows reversals." While the main benefit of Caballero's proposal is macroeconomic stability, another potential benefit is the smoothing of resource output. This may be beneficial not only to individual countries, but also to world capital markets, as it may protect against financial contagion for the reasons noted above.

[29] See Wall Street Journal, February 24, 2009, "Chile Proves Haven for Defensive-Minded," and Wall Street Journal, May 27, 2009, "Prudent Chile Thrives Amid Downturn."

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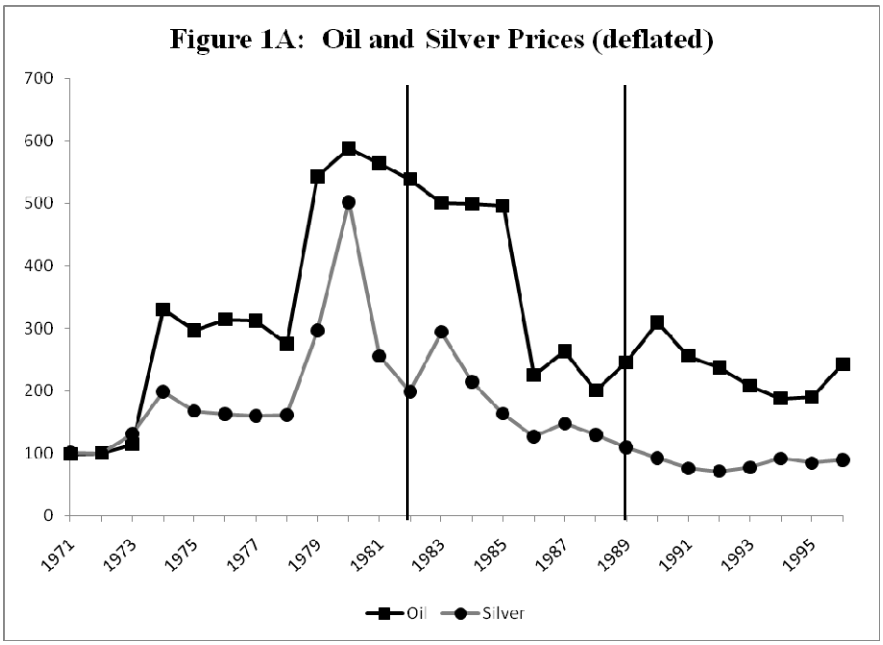

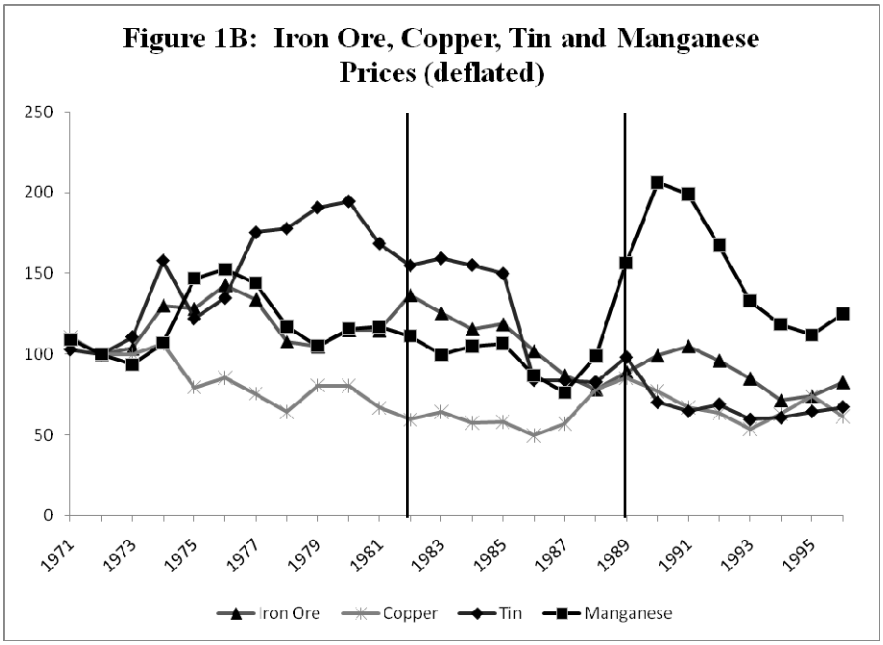

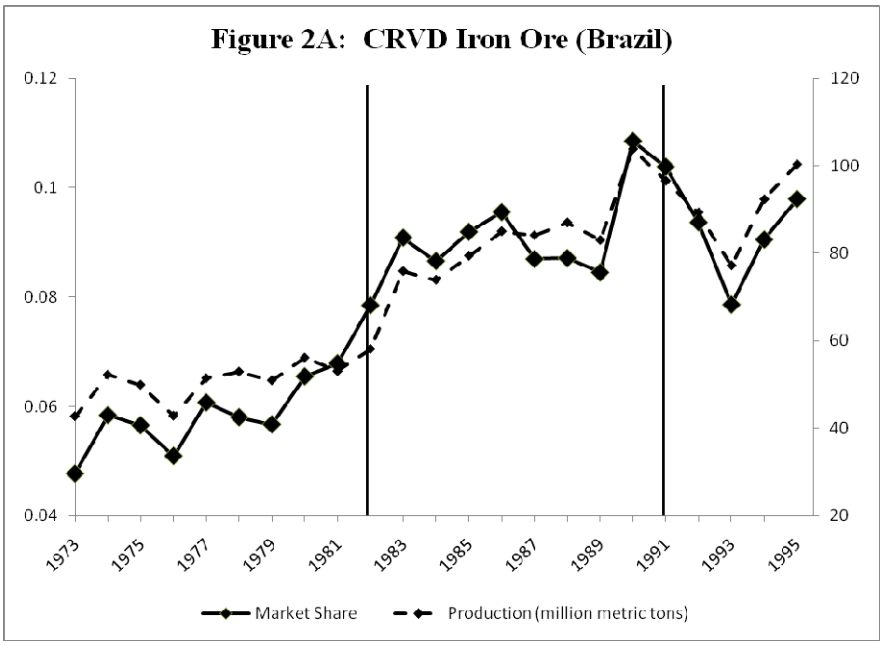

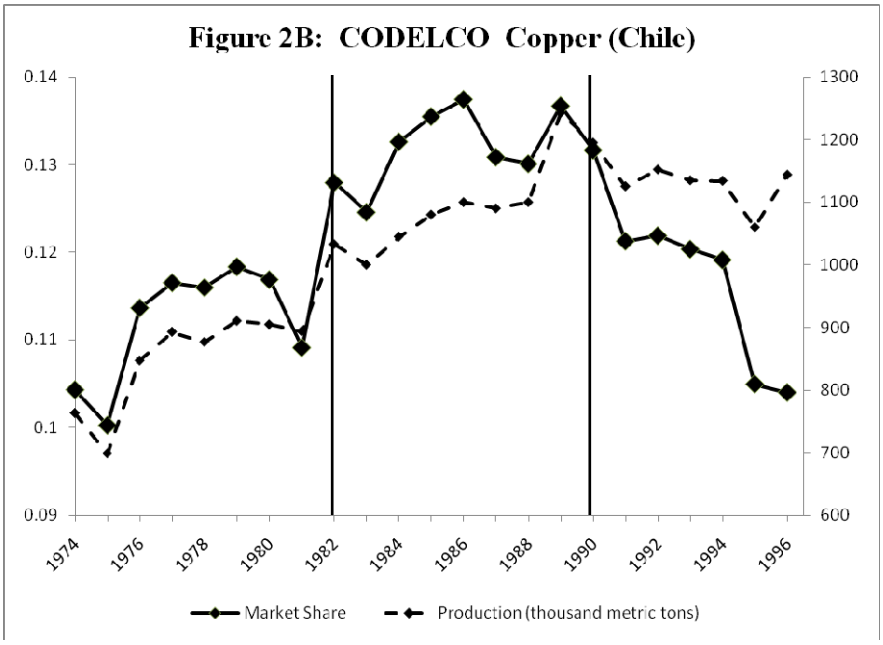

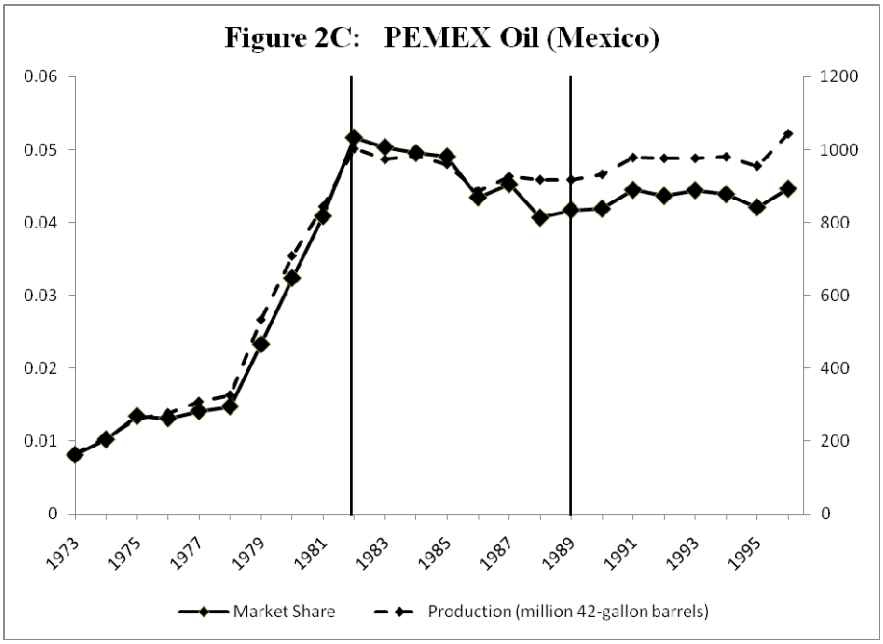

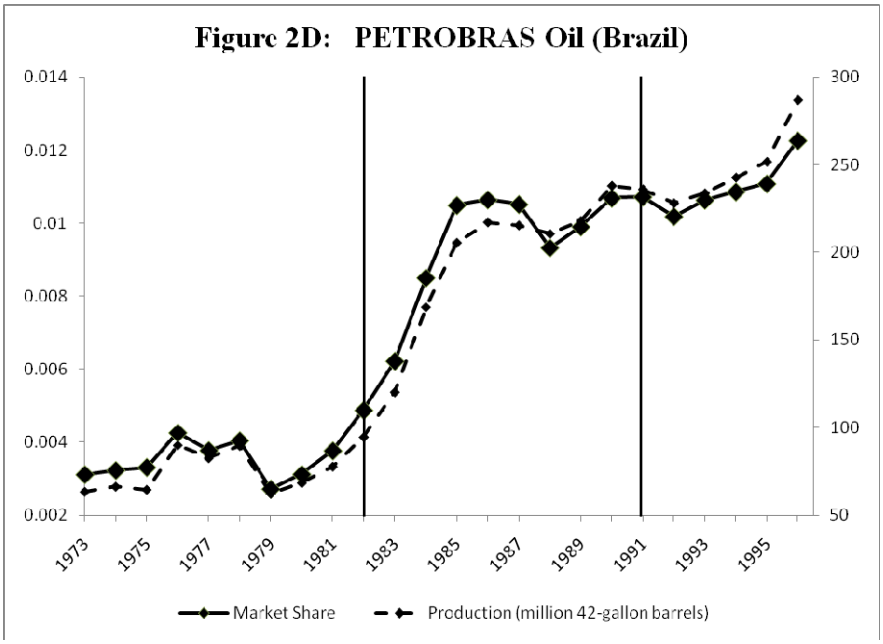

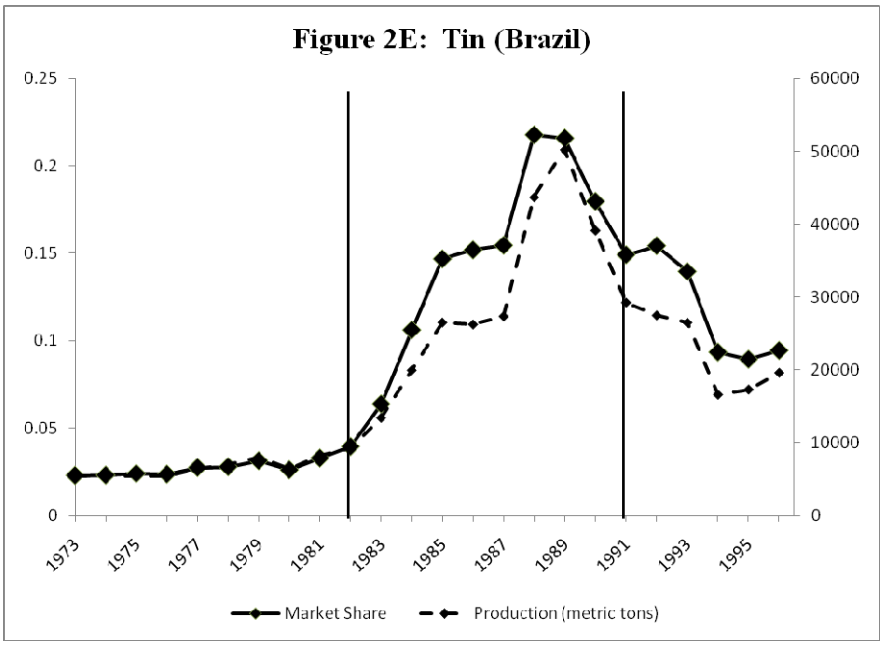

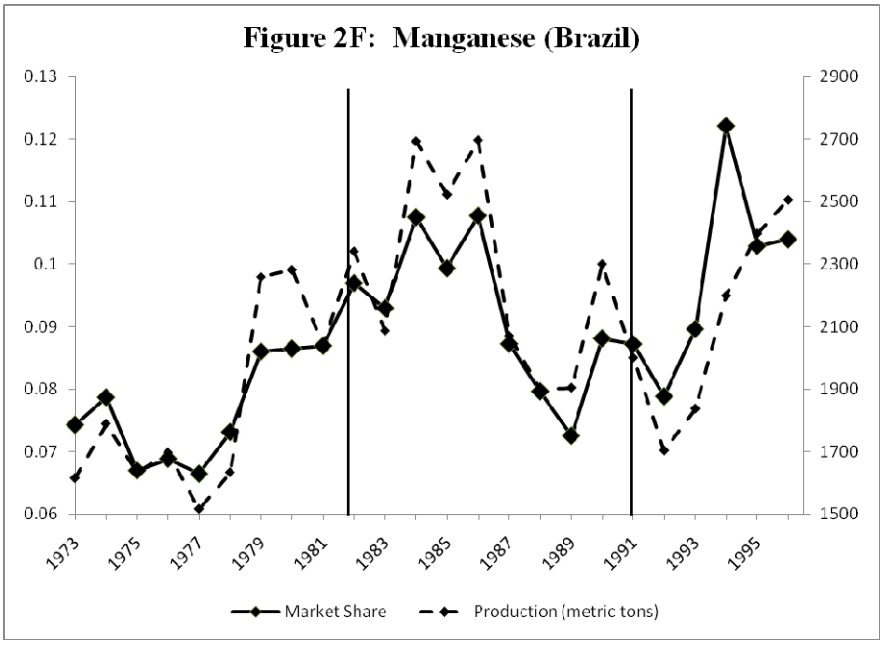

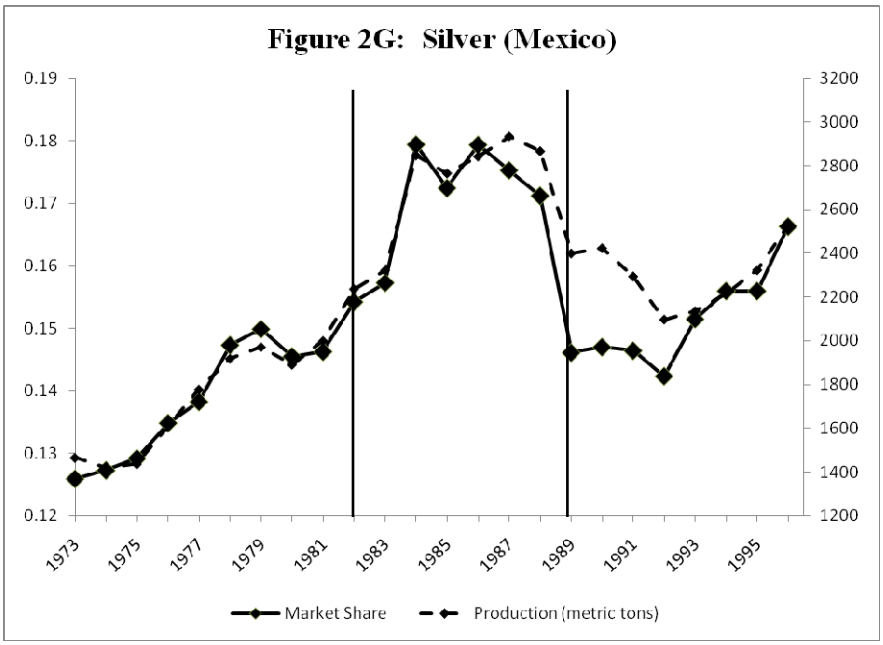

Table 1
Production Regression Results for Key Latin American Countries During 1980s Financial Crisis

Dependent Variable: Log(Quantity of Production)

Mineral, Country	Trend	Log(Price$_{-1}$)	Log(ExRate$_{-1}$)	Crisis Dummy	Log(IntRatio$_{-1}$)	R^2	D.W.	AR order
CVRD Iron Ore, Brazil	0.037*** (0.005)	-0.048 (0.163)	-0.043 (0.115)	0.160*** (0.043)		0.928	1.992	2
	0.039*** (0.008)	0.028 (0.212)	-0.010 (0.170)		0.094* (0.055)	0.905	1.931	2
CODELCO Copper, Chile	0.0151*** (0.002)	0.085 (0.063)	0.040*** (0.010)	0.096*** (0.018)		0.934	1.955	1
	0.016*** (0.002)	0.063 (0.068)	0.014 (0.013)		0.077*** (0.017)	0.933	2.017	1
PEMEX Oil, Mexico	0.053*** (0.007)	0.407*** (0.065)	0.259*** (0.080)	0.114* (0.072)		0.963	2.024	1
	0.050*** (0.007)	0.403*** (0.074)	0.279** (0.115)		0.054 (0.096)	0.958	2.049	1
PETROBRAS Oil, Brazil	0.058*** (0.009)	-0.073 (0.078)	0.438** (0.210)	0.198** (0.086)		0.958	1.624	1
	0.058*** (0.010)	-0.106 (0.103)	0.474* (0.272)		0.108 (0.098)	0.955	2.208	2
Tin, Brazil	0.059*** (0.015)	-0.154 (0.203)	0.181 (0.331)	0.759*** (0.131)		0.920	1.684	1
	0.034 (0.021)	-0.625* (0.311)	0.442 (0.438)		0.578*** (0.158)	0.905	1.337	2
Manganese, Brazil	0.008 (0.009)	-0.107 (0.180)	0.147 (0.243)	0.106 (0.080)		0.549	1.713	1
	0.006 (0.009)	-0.087 (0.175)	0.137 (0.232)		0.104* (0.062)	0.565	1.785	1
Silver, Mexico	0.019*** (0.006)	0.101* (0.059)	0.093 (0.063)	0.184*** (0.053)		0.907	1.788	2
	0.016*** (0.004)	0.022 (0.042)	-0.068 (0.059)		0.297*** (0.044)	0.944	1.884	2

Each regression is estimated from 24 annual observations over the period 1973 to 1996. The crisis dummy equals one during 1982-1989 for Mexico, 1982-1991 for Brazil, and 1982-1990 for Chile. Int Ratio$_{-1}$ is defined as public interest divided by GNP. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels.

Table 2
Market Share Regression Results for Key Latin American Countries During 1980s Financial Crisis

Dependent Variable: Log(World Market Share)

Mineral, Country	Trend	Log(ExRate$_{-1}$)	Crisis Dummy	Log(IntRatio)$_{-1}$	R^2	D.W.	AR order
CVRD Iron Ore, Brazil	0.027*** (0.008)	0.055 (0.105)	0.181*** (0.038)		0.913	2.088	2
	0.029*** (0.005)	0.043 (0.147)		0.135*** (0.043)	0.894	2.034	2
CODELCO Copper, Chile	-0.002 (0.002)	0.031** (0.012)	0.133*** (0.024)		0.819	1.804	2
	-0.002 (0.003)	0.011 (0.015)		0.094*** (0.019)	0.74	1.905	1
PEMEX Oil, Mexico	0.043*** (0.012)	0.294*** (0.117)	0.326*** (0.115)		0.929	1.400	2
	0.046*** (0.012)	-0.003 (0.171)		0.441*** (0.158)	0.932	1.294	2
PETROBRAS Oil, Brazil	0.051*** (0.010)	0.537* (0.235)	0.204** (0.087)		0.955	2.039	2
	0.053*** (0.011)	0.531* (0.285)		0.061 (0.089)	0.945	2.216	2
Tin, Brazil	0.067*** (0.013)	0.573 (0.344)	0.686*** (0.135)		0.934	1.783	2
	0.065*** (0.019)	0.706* (0.412)		0.282** (0.135)	0.958	1.512	2
Manganese, Brazil	0.006 (0.007)	0.287* (0.177)	0.043 (0.069)		0.611	1.838	1
	0.006 (0.007)	0.300 (0.181)		0.009 (0.059)	0.604	1.937	1
Silver, Mexico	0.003 (0.003)	0.067* (0.035)	0.075** (0.035)		0.795	1.798	2
	0.004 (0.003)	0.002 (0.045)		0.105** (0.041)	0.822	1.945	2

Each regression is estimated from 24 annual observations over the period 1973 to 1996. The crisis dummy equals one during 1982-1989 for Mexico, 1982-1991 for Brazil, and 1982-1990 for Chile. Int Ratio$_{-1}$ is defined as public interest divided by GNP. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels.

Table 3
Regression Results for Indonesia and the U.S. During 1980s Financial Crisis

Mineral, *Dependent Variable*	Trend	Log(Price$_{-1}$)	Log(ExRate$_{-1}$)	Crisis Dummy	R^2	D.W.	AR order
			Indonesia				
Tin, *Log(Quantity)*	0.020*** (0.004)	-0.079 (0.158)	-0.589** (0.215)	-0.044 (0.034)	0.782	2.054	2
Tin, *Log(MktShare)*	0.022*** (0.003)		-0.353** (0.146)	-0.027 (0.029)	0.837	1.801	1
Nickel, *Log(Quantity)*	0.034*** (0.004)	0.099 (0.130)	-0.303* (0.156)	0.029 (0.031)	0.919	1.935	1
Nickel, *Log(MktShare)*	0.027*** (0.005)		-0.377* (0.205)	0.047 (0.041)	0.824	1.819	1
LNG, *Log(Quantity)*	0.059*** (0.006)	0.179 (0.126)	-0.506* (0.291)	0.073 (0.051)	0.966	1.610	2
Oil, *Log(Quantity)*	0.005*** (0.001)	0.004 (0.029)	-0.184*** (0.060)	-0.053*** (0.010)	0.755	2.016	1
Oil, *Log(MktShare)*	0.002** (0.001)		-0.162*** (0.043)	-0.022** (0.008)	0.567	1.894	1
			United States				
Copper, *Log(Quantity)*	0.017*** (0.004)	0.324** (0.151)		-0.214*** (0.055)	0.728	1.759	1
Copper, *Log(MktShare)*	-0.003 (0.003)			-0.222*** (0.046)	0.641	1.793	2
Silver, *Log(Quantity)*	0.023*** (0.005)	0.018 (0.071)		-0.072 (0.065)	0.813	1.602	2
Silver, *Log(MktShare)*	0.011** (0.004)			-0.169*** (0.055)	0.744	1.914	2
Iron Ore, *Log(Quantity)*	-0.029*** (0.008)	-0.813** (0.303)		-0.193** (0.085)	0.609	1.986	2
Iron Ore, *Log(MktShare)*	-0.020*** (0.005)			-0.201*** (0.072)	0.640	1.980	2

Each regression is estimated from 24 annual observations over the period 1973 to 1996. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels. The crisis dummy equals one during 1982-1989.