Chapter 1

INTRODUCTION

Mining and the consumption of nonrenewable mineral resources date back to the Bronze Age, indeed even the Stone Age. So for millennia, they have made the lives of people nicer, easier, and more secure.

What is new is the pace of exploitation. The human race has consumed more aluminum, copper, iron and steel, phosphate rock, diamonds, sulfur, coal, oil, natural gas, and even sand and gravel over the past century than over all earlier centuries put together. Moreover, the pace continues to accelerate, so that today the world annually produces and consumes nearly all mineral commodities at record rates.

Several underlying forces are driving this explosion in use. First, advances in technology allow the extraction of copper, coal, and many other mineral commodities at increasingly lower costs. Advances in technology also permit new and better mineral commodities serving a range of new needs. Second, rapidly rising living standards in many parts of the globe are increasing the demand across the board for goods and services, including many that use mineral commodities intensively in their production. Third, the surge in world population means more and more people with needs to satisfy. Of these forces, only population growth shows any sign of abating.

The sharp rise in mineral consumption and production has, understandably, raised concerns about the long-run availability of mineral commodities. Since mineral resources are by nature nonrenewable, their supply is a fixed stock. The earth contains only so

much oil, copper, and other mineral commodities. Demand, on the other hand, continues year after year. As a result, many believe that it is just a matter of time before the availability of mineral supplies is threatened. Should the rate of mineral exploitation continue to grow as it has over the past several decades, mineral depletion, it is argued, is likely to create serious problems sooner rather than later. Moreover, as society is forced to exploit lower grade and more remote deposits, the environmental and other social costs associated with producing and using mineral commodities are likely to rise, perhaps limiting their use even before depletion.

Concern over the long-run availability of mineral resources, however, is not universal. On the other side of the debate are those who believe that the market coupled with appropriate public policies is sufficiently robust to deal with any threats. Pending shortages push mineral prices up, which in turn unleashes a host of countervailing forces. Exploration rises, increasing the likelihood of new discoveries. Research and development produces new technologies that allow the recovery of mineral commodities from previously unusable resources. Less scarce, and possibly renewable, resources are substituted for minerals facing growing shortages.

The stakes are not trivial. Nonrenewable resources matter. Long-run availability has consequences for the world's ability to sustain its current population, let alone accommodate increases, for lifestyles and living standards, and indeed for modern civilization as we know it.

As Chapter 2 shows, the debate over resource availability is not new. It can be traced back at least 200 years to the Classical economists, though the past 30 years have been particularly active. Much of the recent literature, however, is technical, written by

economists and other specialists in a manner that the interested layperson often finds difficult to follow.

Purpose and Scope

This study proposes to provide a framework for analyzing the on-going debate over mineral resource availability, and to review the important literature in a manner that the non-specialist can appreciate. It attempts to answer a number of questions: What have we learned? Where is there now widespread agreement among the experts? Where do they continue to disagree, and why? What are the important implications of what has been learned?

The focus is on the long-run availability of mineral commodities, or what is often called the mineral depletion problem or the mineral exhaustion problem. We do not address availability problems that arise for reasons other than mineral depletion. Strikes, cartels, price controls and other government policies, monopolies, adverse weather, accidents, booms in the business cycle, and even insufficient investment in exploration and mineral development can all for a time cause shortages of mineral commodities. Such shortages in almost all cases are temporary, lasting from a few days to perhaps a decade. Though they can cause considerable dislocation and hardship while they last, they fall outside the scope of this inquiry.

Terminology

Availability, as the term is used throughout this study, reflects the opportunity cost, or what has to be given up in terms of other goods and services, to obtain a mineral commodity. If availability is declining, this implies that over time more of other goods and services must be foregone to get an additional unit. With this definition, trends in availability reflect the extent to which mineral depletion is a growing threat to the long-run welfare of society. In practice, as Chapter 3 will discuss, there are many measures and definitions of mineral resource availability, all of which have their limitations.

Along with availability, we need to define what we mean by shortages and scarcity. These terms are often used to reflect an excess of demand over supply at the prevailing market price. Such situations are unusual, since normally when demand exceeds supply price rises bringing the two back into equilibrium. Of course, they can occur if governments or companies control prices. For our purposes, however, this definition is too narrow. When real prices are rising, the opportunity costs in terms of what we have to give up to get a mineral commodity are also rising. As a result, we use the terms shortage and scarcity to mean the opposite of availability. A growing shortage, for example, implies declining availability, and may occur even though demand and supply are in balance.

We also need to distinguish between mineral resources and mineral commodities, and between renewable and nonrenewable resources. Mineral commodities, such as copper, are produced from mineral resources, such as chalcopyrite and other copper-containing minerals. Mineral resources are the legacy of geological processes that took place over many thousands of years, often in the distant past. Since the time required for their formation is so vast from the perspective of any meaningful time scale for people,

mineral resources are considered nonrenewable. In contrast, many other resources, such as water, air, forests, fish, and solar energy, are considered renewable. One advantage of renewable resources is that their current exploitation need not result in less being available in the future. Just how significant the difference is between nonrenewable and renewable resources, however, is another issue, one we will return to in Chapter 7.

Organization

The presentation following this introduction is organized in the following manner. Chapter 2 examines the historical evolution of concerns over the long-run availability of mineral resources. It reviews the pioneering works of Thomas Malthus, David Ricardo, and Harold Hotelling, as well as the much more abundant literature since the 1970s.

Chapter 3 identifies different measures used to assess long-run trends in resource availability, and assesses their strengths and weaknesses. It considers physical measures, such as reserves and the resource base, as well as purely economic measures, such as real costs and real prices. It explores the concepts of user costs, economic and physical depletion, as well as Ricardian and Hotelling rents. It raises the possibility that mineral commodities may become more, rather than less, available over time.

Chapter 4, using measures described in Chapter 3, examines trends in resource scarcity over the past century. It covers the seminal work of Harold Barnett and Chandler Morse on production costs, along with the more recent work of Margaret Slade and others on mineral commodity prices. It finds that mineral resources, despite their widespread and accelerating use, have not become more scarce over the past century.

Chapter 5, acknowledging that past trends are not necessarily a good guide to the future, looks at the availability of mineral commodities over the near term (the next 50 years) and the more distant future. It examines the work of Brian Skinner on the geological nature of mineral deposit formation, and its implications for future scarcity. It also introduces the cumulative supply curve, a conceptual technique for categorizing the various factors shaping future trends in mineral resource availability. The chapter finds that the distant future with respect to mineral resource availability is at this time unknown, which helps explain why the debate over this issue continues. But it also suggests that society, if it wishes and is willing to cover the costs, can obtain considerable information on the prospects for future shortages by carrying out more research on the nature and incidence of sub-economic mineral deposits.

Chapter 6 turns to the environmental and other social costs associated with mineral exploitation, and assesses the threat they pose to the long-run availability of mineral commodities. It examines the ability of public policy to force mineral-producing firms to pay their full costs of production, particularly in light of the difficulties of measuring social costs and of regulating small-scale artisanal mining. It also assesses the ability of mineral-producing companies to reduce costs, assuming all social costs are internalized, by new technology and other means. This chapter ends by suggesting that economists and other social scientists are likely to play an increasing role in society's efforts to keep the adverse effects of mineral depletion at bay, complementing the important contributions that engineers and physical scientists have traditionally made.

Chapter 7, the final chapter, highlights the findings, and explores their implications for sustainable development, for green accounting, for the protection of

indigenous cultures and other social goods, for conservation, recycled materials, and renewable resources, and for global population. Among other things, this chapter suggests that the link between mineral resource availability and sustainable development is much looser than many presume. Declining resource availability need not prevent sustainable development, just as growing resource availability does not ensure it.