ECONOMICS OF METAL MARKETS

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FOREWORD

The influence of research on public policy is often not easy to discern. Still, most of us engaged in policy oriented research continue in the belief, the faith, that there is a connection between the two. Good research that enhances our understanding of how metal firms and markets behave must somehow, ultimately, produce better policies.

Assuming this is true, certainly one of the important links in the chain connecting research and policy is education, and the dissemination of the new knowledge that research generates. In the field of mineral economics, the American Institute of Mining, Metallurgical, and Petroleum Engineers has over the last quarter of a century played an important role in this regard through its support for *Economics of the Mineral Industries*. This book was first published in 1959, and has since been revised twice. It is widely used both as a textbook and a reference volume.

The fourth edition of *Economics of the Mineral Industries* is now being prepared, and will contain a chapter on metals. This working paper is a draft of that chapter. It will be revised before publication, and is being circulated now for comments, criticism, and suggestions.

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ABSTRACT

Simple economic principles can provide useful insights into the behavior of metal markets. In applying these principles, however, the analyst must take into account technology, market structure, government policies, and other institutional factors influencing the nature of metal supply and demand. Knowledge of both economics and the metal markets is essential. One without the other is likely to lead to sterile or even misleading results.

In support of the above conclusion, this study examines the nature of metal supply and demand in the immediate run (when output is fixed), in the short run (when capacity is fixed), in the long run (when technology and known deposits are fixed), and in the very long run (when nothing is fixed).

The first section considers how a metal's own price, the prices of substitutes and complements, income, and other factors determine its demand. Metal demand functions, demand curves, and demand elasticities are investigated.

The second section focuses on metal supply. It contrasts the nature of supply for metals mined as individual and main products, recovered as byproducts and coproducts, and recycled from old and new scrap.

The third and final section applies the concepts introduced in the first two sections. It analyzes the causes and consequences of the instability that plagues metal markets, the impact of public stockpiling on metal markets, and the conditions needed to use the "incentive price" technique to forecast long run metal prices.

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INTRODUCTION

Mineral commodities are normally separated into three generic classes - metals, non-metals, and energy minerals including oil and gas as well as the solid fuels. Metals, the focus of this chapter, encompass a large number of different substances. The U.S. Bureau of Mines, for instance, has commodity specialists following trends in over 40 metal products of importance to the country's economy and well being.

Ranging from aluminum to zirconium, the metals display an incredible degree of diversity. Some such as lead are heavy, others such as magnesium are light. Some such as copper are good conductors of electricity. Others such as silicon are semiconductors.

Mercury is found in liquid form, while some metals melt only when heated to extremely high temperatures.

Iron and steel, aluminum, and copper are consumed in particularly large tonnages in a multitude of end uses, while many minor metals are needed in only small amounts in a few highly specialized applications. The use of some metals can be traced back into history for millennia, indeed back to the bronze and iron ages, while the commercial consumption of aluminum and other newer metals is less than a hundred years old.

Some metals are extracted from large open pits, others are dug out of deep underground mines, and still others are processed from the sea. Mining and processing can be relatively uncomplicated and inexpensive, though in most instances highly sophisticated technology is necessary and the costs are high. Some metals are produced mainly as by-products of other metals. Some are recovered in large quantities from the scrap of obsolete equipment and demolished buildings. Some are mined in only a few locations and traded worldwide, others are produced in many different countries. Some are sold by numerous firms at fluctuating prices determined on competitive commodity exchanges, others are produced by only a handful of firms and sold at stable producer prices.

It is this diversity that makes the metals interesting, indeed fascinating, to study. Yet, it also poses problems, for each metal in its own way is unique. There is no general model or economic analysis applicable to all metals. Rather each must be considered individually, so that the analysis or model takes explicit account of its particular features.

This means that a single chapter cannot begin to cover comprehensively the economics of all metals, and no attempt to do so is made here. Instead, we will concentrate on illustrating the usefulness of relatively simple economic principles, particularly those associated with supply and demand analysis, in understanding the behavior of metal markets. The next section begins by exploring the nature of metal demand. It is followed by an investigation of metal supply--from individual product production, from byproduct and coproduct production, and from secondary production. The final section then illustrates the usefulness of the concepts introduced in earlier sections by using them to analyze the causes and consequences of metal market instability, to appraise the market impacts of public stockpiling, and to assess the "incentive price" technique for forecasting long run metal prices.

There is one particularly important conclusion that the following pages should make clear. The simple tools of economics can provide powerful insights into the operation and behavior of the metal markets, but only if the analyst applying these tools has a firm understanding of the important technological and institutional relationships governing the metal market he is examining, and can tailor his analysis so as to take these relationships explicitly into account. Studies by good economists who apply their theoretical concepts in ignorance of important technological and institutional constraints are almost inevitably sterile and misleading. The same can also be said for commodity specialists, who may know well the relevant institutions and technologies but who lack a basic understanding of economic principles. Good analysis requires knowledge of both economics and the particular metal of interest.

METAL DEMAND

Metals, at least in their unwrought form, rarely are final goods. The only exception that comes readily to mind is the hoarding of gold and other precious metals as a store of value, and even here one might argue that it is the goods and the services these metals will eventually buy that are of interest to the hoarder, not the metals themselves.

Rather metals are in demand because they possess certain qualities or attributes, such as strength, ductility, heat conductivity, resistance to corrosion, that are needed in the manufacturing of final consumer and producer goods. This means that the demand for metals depends on the demand for final goods, and for this reason is often characterized as a derived demand. Since demand is really for a set of attributes, rather than for a metal per se, in many end uses one metal can replace another, or even a non-metallic material, such as a plastic or ceramic.

The importance of material substitution is highlighted in the discussion that follows on the major determinants of metal demand. We then review three economic concepts - the demand function, the demand curve, and demand elasticities - and their uses in metal demand analyses.

Major Determinants

Literally thousands of factors affect the demand for metals - poor weather in the mid-West of the USA and the resulting consequences for agricultural income and farm equipment sales, the rising price of petroleum and the stimulus it provides for oil exploration, a decision by the French government to modernize part of its naval forces, a World Bank loan to Brazil to build a dam and hydroelectric power station.

Clearly, however, some factors are more important than others. We would expect, for example, the price of aluminum to have a greater impact on the demand for that commodity than the price of oil, even though the latter presumably does have some influence on aluminum demand. Higher oil prices, for instance, encourage automobile manufactures to substitute aluminum for heavier materials to increase gasoline mileage.

In analyzing metal demand, it is not possible to take account of all possible determinants. There simply are too many. Moreover, the effects of most are so trivial they can be safely ignored, and indeed should be ignored so as to avoid needlessly complicating the analysis. The problem is deciding which factors are of such importance they need to be considered. The answer depends not only on the metals of interest, but also on the purpose and time horizon of the analysis. Technological change, for example, is not likely to alter greatly the demand for zinc over the next three months, as new innovations normally take a number of years to introduce and diffuse. So in assessing demand over the next quarter, we can usually safely ignore technological change. On the other hand, an analysis of zinc demand in the year 2020 would need to consider carefully the effects of new technology.

The choice of which factors to consider and which to ignore is important, and will to a large extent determine the quality of the analysis. In this regard, it is useful to review those determinants often considered in metal demand studies.

1. Income

Metals are used in the production of consumer and producer goods. So changes in the output of either have a direct and immediate impact on metal demand. In this connection, two types of changes in aggregate production or income are often distinguished: the first encompasses relatively short run changes that come about largely as a result of fluctuations in the business cycle; the second covers longer run changes caused by secular growth and structural change in the economy.

As income is one of the most important variables affecting metal demand, its influence is almost always taken into consideration. In many studies, gross national product (GNP), gross domestic production (GDP), or some alternative measure of national income is employed to assess the influence of this variable. More disaggregated measures of income are also used. For example, in assessing the demand for copper wire, we might use the production of electrical and electronic equipment to capture the effect of income fluctuations.

2. Own Price

A metal's own price is also normally an important determinant of demand. Demand tends to fall with an increase in price, and rise with a decline in price. There are two reasons for this inverse relationship. First, a higher metal price increases the production costs of the final goods in which it is used. If these costs are passed on to the consumer in the form of higher prices, then demand for the final goods, on which the demand for the metal is based, will fall. This is because consumers with given incomes will now be able to buy less (the income effect), and because they may now shift their consumption in favor of other goods whose prices have not risen (the substitution effect). Second, manufacturers are motivated to substitute other materials for the higher price metal in the production of their final goods. Indeed, this latter response by producers usually has a much greater impact on metal demand than that induced by consumers through a reduction in the demand for the final goods. This is because in most of their end uses metals account for only a very small percentage of total production costs. The cost of the steel in an automobile, for instance, represents less than one-tenth of the latter's price, so an increase of ten percent in the price of steel raises the price a consumer must pay for a new automobile by less than one percent.

It is important, however, to note that material substitution by producers takes time. New equipment is often necessary, personnel may have to be recruited or retrained, and production techniques must frequently be altered. Consequently, the initial effect on demand of a change in a metal's price may be quite modest, and a number of years may be needed before the full effect is realized.

3. Prices of Substitutes and Complements

The demand for a metal may be affected by prices other than its own. Most metals compete with other materials for their end use markets, and so a fall in the price of any such substitute can adversely affect the demand for the others. Wood, brick, aluminum, and plastic, for example, have all been widely used in home construction as external siding. In recent years the decline in the price of plastic siding has encouraged its widespread use, and aluminum has been all but eliminated from this once important market.

In some instances, a fall in the price of one material may actually increase demand for another. In such cases, we say the two materials are complements. For example, a fall in the price of steel tends to increase the use of tinplate, since tinplate is composed primarily of steel. This, in turn, stimulates the demand for tin. Consequently, in end use markets for tinplate, steel and tin are complementary materials.

As with changes in own price, changes in the prices of substitutes and complements affect metal demand primarily by inducing producers to alter the nature of their manufacturing processes. Consequently, some time is required for the full impact of price changes on demand to be realized.

4. Technological Change

New technology can alter demand in several ways. First, it can reduce the amount of metal required in the production of specific items. For example, the amount of tin consumed in manufacturing a thousand beer cans fell from over two and a half pounds per thousand in the 1930s to under half a pound by 1957, largely as a result of the development of electrolytic tinning and its widespread use in place of the older, less efficient, hot-dip process for making tinplate (Demler, 1983).

Second, new technology can affect the ability of a metal to compete in particular end use markets. This is nicely illustrated by the waterpipe market for home construction, where innovations in the production of polyvinyl chloride (PVC) plastic pipe have allowed this material to capture a sizable market share over the last twenty years. In the process, the demand for copper and other traditional pipe materials has suffered. In contrast, the demand for tin, needed to manufacture the organotin chemicals required in the production of PVC plastic, has been stimulated (Gill, 1983).

Finally, new technology can change the number and size of end use markets. The advent of the automobile, for instance, gave rise to a major new market for steel. The same development, however, led to a contraction in steel's use for the production of carriages and horse shoes. Germanium, whose widespread use in the production of transistors and diodes in the 1950s was the direct result of new technology, suffered during the 1960s as new planar technology and other developments made silicon chips the preferred material for transistors, integrated circuits, and other semiconductor devices.

Since measuring technological change is difficult, some studies ignore this particular determinant. This may not be serious when assessing demand over a very short period, for as pointed out earlier, the introduction and dissemination of new technology takes time. Over the longer term, however, it is much harder to rationalize the exclusion of this variable. Other studies simply assume that technological change is closely correlated with time. This allows the use of a time trend to capture the effects of technological change. While such a procedure may be acceptable in some situations, in most the influence of technological change is too random and discrete. The tremendous impact that electrolytic tinning had on the demand for tin was basically a once-and-for-all event. The effects of such major innovations are not likely to be closely correlated with time, and should be explicitly and individually taken into consideration.

5. Consumer Preferences

Changes in consumer preferences alter the number and magnitude of end use markets in which metals are consumed. Over the last decade the American public has experienced an on-again-off-again love affair with the small car, orchestrated to some extent by fluctuations in the availability and real price of gasoline. Small cars are imported in large numbers, and in any case use less steel, copper, aluminum, and other materials. So when preferences shift towards small cars, the domestic demand for metals by the motor vehicle industry tends to fall.

Consumer preferences may vary over time and among countries for a number of reasons. The age distribution of the population, for example, can be important. Between the ages of 18 and 35, many individuals are engaged in setting up new family units, and spend a relatively large proportion of their income on housing, automobiles, refrigerators, and other consumer durables needed in establishing new homes. Over the last several decades, the population in the United States and other developed countries has grown older. As a larger proportion of the total falls into the over 35 age bracket, preferences are likely to shift to less material intensive goods, reducing metal demand.

Per capita income and the overall level of economic development also influence consumer preferences. The poor have to spend their limited incomes almost entirely on basic necessities, while the rich can indulge in more luxuries. The rich also tend to save a large portion of their income. So a shift of income in favor of the poor is likely to reduce the amount of total income invested. Since investment stimulates the construction, capital equipment, and other material intensive sectors of the economy, such a redistribution may reduce the demand for metals and other materials.

New technology by making new and better products available also causes shifts in consumer preferences. The rapid growth of the airline industry over the last 50 years has substantially increased the use of aluminum and titanium in this market, while reducing the consumption of steel in railroad passenger cars and ocean liners.

Finally, even if the age distribution population, per capita income, income distribution, and the quality and choice of product dictated by existing technology remain constant, consumer preferences can change simply in response to shifts in personal tastes. In some incidences, these shifts are influenced by higher related costs, as the jump in demand for small cars in response to sharp increases in the real price of gasoline illustrates. In other cases, the shifts may be influenced by advertising, or psychological considerations that are not fully understood.

Normally, consumer preferences evolve slowly over time, as the demographic, income, and other important factors just discussed seldom change quickly. There are, of course, exceptions, as again the surge in consumer preference for small cars following the sharp increase in oil prices in 1974 and 1979 illustrate. Still, changes in consumer preferences usually have a much greater impact on metal demand over the longer term.

6. Government Activities

Government policies, regulations, and actions constitute another major determinant of metal demand. This is perhaps most dramatically and starkly illustrated when government policies lead to war. At such times, a substantial portion of a country's resources are redirected towards the production of arms and defense related activities. The demand for aluminum, nickel, cobalt, molybdenum, titanium, and other metals surges with the output of ships, tanks, aircraft, ammunition, trucks and other military vehicles.

In peace time, government activities also influence metal demand in a number of ways. Changes over time in government expenditures on education, defense, research and development, highways, and other public goods alter the output mix of the economy. Fiscal, monetary, and social welfare policies affect income distribution, and the overall level of investment and economic growth. Worker health and safety legislation, environmental standards, and other governmental regulations may proscribe certain materials in particular end uses. Local building codes, for example, for many years retarded the use of plastic water pipe in parts of the United States, helping to maintain the demand for copper in this particular market (Gill, 1983).

Because government actions and their effects on metal demand are not always easy to identify and quantify, they are often ignored. Unfortunately, they are also often important, and on occasions produce substantial shifts in metal demand even in the short term.

The Demand Function

The relation between the demand for a metal and its major determinants, such as those we have just discussed, is given by the demand function. This economic relationship is often expressed mathematically. In some analyses, for example, demand during year t (Q_t^d) is assumed to depend on only three variables - income during year t (Y_t), own price during year t (P_t^o), and the price of its principal substitute during year t (P_t^s).

$$Q_t^d = f\,(Y_t, P_t^o, P_t^s) \qquad (1)$$

Several things about Equation 1 are worth noting. First, it is a rather simple demand function, indeed too simple to be useful in most instances. This is in part because it recognizes only three variables affecting demand. In most situations, as we have seen, there are other important determinants that belong in the demand function.

Second, Equation 1 considers only the immediate or short run effects on demand of changes in its determinants. For the income variable, this is not a serious shortcoming, since metal demand tends to respond rather quickly to changes in the overall level of economic activity. This is not the case for prices. Producers take time to substitute one material for another, and in other ways to respond fully to a change in a metal's own price or that of its principal substitutes. This means that demand this year depends not only on prices this year, but also on prices a year ago, two years ago, and so on for as far back as past prices affect current consumer demand. Thus, at best, Equation 1 provides an indication of the short run response of demand to changes in price.

Third, while Equation 1 identifies important variables presumed to influence demand, it does not specify the nature of the relationship. Normally, a rather simple specification between demand and its determinants is assumed. A linear or log linear relationship, similar to those shown in Equations 2 and 3, are particularly popular, primarily because they are relatively simple and easy to estimate. Unfortunately, such specifications entail rather strong assumptions about the nature of the demand function, whose validity is often difficult to assess.

$$Q_t^d = a_0 + a_1 Y_t + a_2 P_t^o + a_3 P_t^s \tag{2}$$

$$\log Q_t^d = b_0 + b_1 \log Y_t + b_2 \log P_t^o + b_3 \log P_t^s \tag{3}$$

The Demand Curve

In analyzing metal markets, we at times focus on one particular variable and try to assess how it alone affects demand. For example, if the U.S. economy is expected to grow by 5 percent over the coming year, aluminum firms need to know how this will alter their demand.

Another variable whose influence is often of special interest is price, particularly a commodity's own price. The demand curve, which is frequently encountered in mineral analyses, economic textbooks, and elsewhere, portrays the relationship between price and demand. More specifically, it shows how much of a commodity can be sold at various prices over a year or some other time interval, on the assumption that income, the prices of substitutes, and other determinants of demand remain fixed at certain designated levels.

Normally, demand curves are drawn with a downward slope, like those shown in Figures 1 and 2. Intuitively, one would expect demand to fall as price rises, and in standard economic textbooks the downward slope is derived from the theory of consumer behavior and the theory of the firm. Still, there can be exceptions. In special circumstances, the demand curve can, at least over a significant segment, be vertical (implying that consumers want a particular amount of the commodity, no more and no less, regardless of its price), horizontal (implying that above a particular price consumers demand none of the commodity while below that price their demand is insatiable), and upward sloping (implying that consumers actually increase their demand as price goes up). Such situations are rare, but when they do occur are likely to be of considerable interest and importance.

Several other characteristics of the demand curve are also important to remember:

1. A movement along the curve reflects the effect of a change in a commodity's own price. A change in any of the other variables influenc-

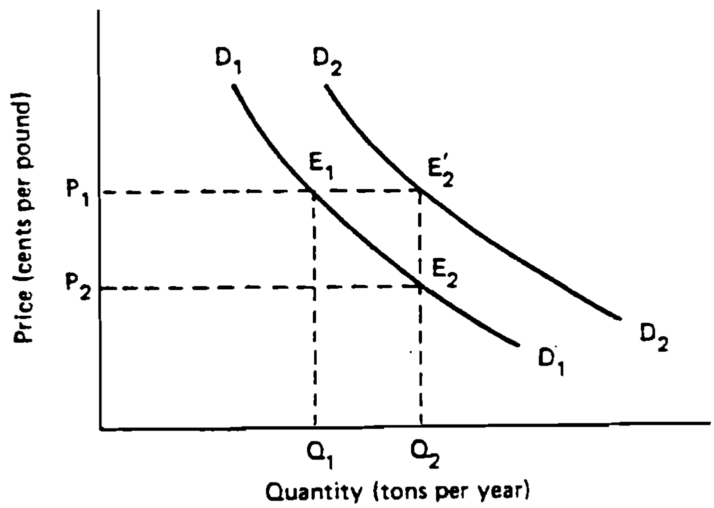


Figure 1. Movements along and Shifts in the Demand Curve

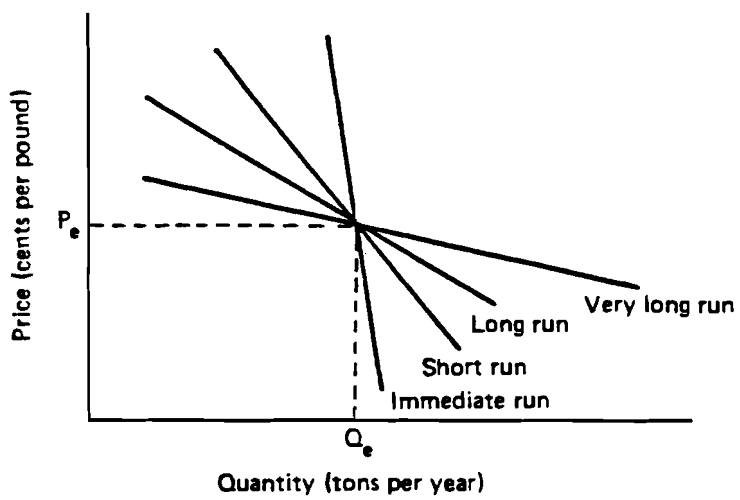


Figure 2. The Demand Curve in the Immediate, Short, Long and Very Long Run

ing demand causes a shift in the curve itself. In Figure 1, for example, demand can increase from Q_1 to Q_2, because price falls from P_1 to P_2, causing a movement along the curve DD_1 from point E_1 to E_2. Or, the same increase can occur because the demand curve shifts from DD_1 to DD_2, causing the equilibrium point to move from E_1 to E_2'. Such a shift in the demand curve can occur in response to a rise in income, a new technological development, an increase in the price of a substitute commodity, or a change in one or more of the other demand variables.[1] In using demand curves, it is important to keep the distinction between a movement along the curve and a shift in the curve clear.

At the same time, it should be recognized that a commodity's own price is not always independent of the other demand variables. This makes it difficult at times to isolate price effects, and complicates the use of demand curves. For example, a reduction in the price of aluminum sheet, which is widely used in beverage and food containers, may cause the producers of tinplate to lower their prices to remain competitive. While the fall in the price of aluminum sheet increases demand, the increase is less than would have been the case had the producers of tinplate not also reduced their price. This development can be portrayed as simply a movement down the demand curve for aluminum sheet, or as both a movement down the curve and a leftward shift in the curve. This is because the change in aluminum sheet price has both a direct and indirect effect on demand. The indirect effect results from the fact that the change in aluminum sheet price causes a change in one of the other demand variables, in this case the price of the substitute material tinplate. The first approach attributes both the direct and indirect effects to the change in the aluminum sheet price; the second attributes only the direct effect to the change in this variable. Which approach is better depends largely on the purpose of the analysis.

2. The same commodity may have many different demand curves. At the most aggregate level is the total demand curve, which indicates how much all sellers can sell, or alternatively how much all buyers are willing to buy, at various price levels. On the buyers' side of the market, we can define demand curves for individual buyers, for regional or national markets, for a country's imports, and for particular consuming sectors or industries. We can distinguish between the demand curve for consumers and the demand curve for speculators and hoarders. On the sellers' side of the market, a similar breakdown is possible. So for refined copper, we can identify a demand curve for the world as a whole, for the United States, for the telecommunication sector, for the American Telephone and Telegraph Company, for speculative stocks, for U.S. imports, for U.S. exports, for U.S. producers, for the Newmont Mining Corporation, and so on.

3. The demand curve - and the demand function as well - indicate the demand for a commodity, and not its consumption or production (even though the horizontal axis on the demand curve is sometimes identified as output). Demand is the quantity of a commodity that can be sold at a particular price in a given market over a year or some other time period. If the U.S. government is selling tin from its strategic stockpile, or if speculators or other private stockholders are drawing down their inventories, production may be considerably below demand. Even in the case of a demand curve specifically for producers,

production will be less than demand when producers are liquidating their inventories, and more than demand when they are building up inventories. Similarly, consumption will be above demand when consumers and other buyers are decreasing their stocks, and below demand when they are increasing their stocks.

Over a number of years, the differences between consumption, production, and demand are small, and can safely be ignored. This is because inventory changes over say ten years will largely cancel out, and any remaining differences will be small compared to cumulative demand over such a period. Usually, however, demand curves indicate how much of a commodity is needed over a year or shorter period, and so changes in stocks can cause sizable discrepancies among production, consumption, and demand.

4. The demand curve does not indicate how the effect of a price change varies with respect to time. Rather it assumes, explicitly or implicitly, one specific adjustment period. In this connection, economists typically distinguish between the ***short run***, a period sufficient for firms to adjust output by altering their labor, raw material, and other variable inputs, and the ***long run***, a period long enough for firms to vary their fixed inputs, such as plant and equipment, as well as variable inputs.

In examining metal markets, it is useful at times to consider what we will call the ***very long run***, which provides time not only for all inputs to change, but also for the development and introduction of any new technology induced by price changes. [1] At the other end of the spectrum,

[1] As pointed out earlier, the indirect effect on demand that a price change produces by inducing a change in technology could be treated as a shift in the demand curve rather than a

the *immediate run* is needed in addressing certain mineral issues. It provides so little time for adjustment that firms find it infeasible to alter their output. Only changes in inventories are possible.

As illustrated in Figure 2, the responsiveness of demand to price increases with the adjustment period. In the immediate run price has very little effect, and the slope of the demand curve is very steep. What response there is comes about because price has some influence on the level of stocks that consumers and others desire to hold. In the short-run, some material substitution can occur. On occasions, for example, when strikes in the nickel industry have made it difficult and expensive to obtain this metal, specialty steel manufacturers have used cobalt instead.

Material substitution, however, often requires altering the production process, retraining personnel, and acquiring new equipment. So the opportunities for consumers to resort to substitution in response to changes in material prices are appreciably greater in the long run. Their range of options is further enhanced in the very long run by the new technology induced by material price changes. This technology may also help consumers stretch their material use, allowing them to produce more from a given quantity of steel, aluminum, or chromium. Innovations stimulated by high cobalt and silver prices during the late 1970s and early 1980s have reduced the need for these metals in recent years. Because the full response of demand to price changes is realized only over the very long run, this demand curve exhibits the gentlest

movement along it. In this case, there would be no difference between the long and very long run demand curves. However, neither would reflect the full impact on demand of a change in price over the very long run.

slope in Figure 2.

Just how long the intermediate, short, long, and very long runs are in practice is complicated by the fact that no one answer is valid for all situations. The lag between an infusion of variable inputs and increased output depends on the manufacturing process, and may even vary over time for the same process. Similarly, new capacity can be built more quickly in some industries than others. Normally, we would not expect the immediate run to last for more than several months, and the short run for more than about several years. The shift from the long to the very long run is more difficult to pin down. Some of the new technology induced by a price change may occur quickly, indeed within a year or two, but other developments may take decades before coming to fruition.

The time dimension introduced by the immediate, short, long, and very long runs should not be confused with the time interval over which demand is measured. All of the curves drawn in Figure 2 presume that demand is in tons per year. The very long run demand curve does not indicate how much of a commodity will be demanded over a very long period, for example, over the next twenty years. Rather, it indicates how much will be demanded per year in twenty years time as a consequence of a price change today, assuming price stays at the new level and all other determinants of demand also remain unchanged.

Since neither of these conditions will hold for twenty years, it is best not to think of the very long run demand curve as showing annual demand twenty years from now. What it shows is the new equilibrium towards which demand is moving over the very long run in response to the price change. Long before this equilibrium is actually reached, price and other determinants will change again, causing the trend in demand to shift course and follow a new path towards a different equilibrium.

5. The downward sloping demand curve, as commonly drawn, implies that the relationship between price and demand is continuous and reversible. Continuity means that the demand curve is smooth, like those drawn in Figures 1 and 2, without any kinks or breaks. Reversibility means that if price, after an upward or downward movement, returns to its original level, demand will also return to its original level. In other words, one can move up and back down the same curve in response to price changes without causing the curve itself to shift.

For the immediate and short run demand curves, reversibility seems reasonable. If the desired level of stocks that consumers and others wish to hold declines by a certain amount as price rises, the reverse is likely when price eventually falls. Material substitution that can occur in the short run by its nature involves changes that can be made quickly with minimal costs and disruption. After such a switch, it should be relatively easy to switch back to the original material.

Reversibility is less likely with the long run demand curve. Here, material substitution will entail new equipment, lost production, and other conversion expenses. As a result, a firm will not switch back to a material until its price falls considerably below the level at which its replacement became attractive. In the very long run, the assumption of reversibility is even more doubtful, for now price induced innovations may substantially change the underlying technical and economic conditions governing the demand for a material.

Metal analysts and others often claim that if a material loses a particular market that market will be lost forever. Such statements suggest that a material can not recapture a market lost as its price rises, even if subsequently price returns to its previous level. In other words, after moving up the downward sloping demand curve, an industry may not be able to reverse itself and move back down the same curve, as the conventional demand curve implies.

The assumption of continuity may also not hold, particularly for those metals and materials whose consumption is concentrated in a few major end uses. Over a wide range price may rise with little or no effect on demand. Then, at a particular threshold an alternative material becomes more cost effective in a major application, causing demand to drop sharply. Such discrete jumps or breaks may be found in both short and long run demand curves. They are particularly likely to characterize the very long run demand curve, as price induced innovations by their nature are discrete events. They either do or do not occur. When they do occur, they can have a substantial impact on demand.

Demand Elasticities

In addressing many mineral issues, we need a measure of how sensitive demand is to a change in price. In the mid-1970s, for example, there was widespread concern that the International Bauxite Association might become a cartel and sharply increase world bauxite prices, just as the Organization of Petroleum Exporting Countries had raised the price of oil. To operate successfully a cartel must be able to raise price without a large loss in market demand. So there was at that time much interest in the possibility that aluminum might be economically produced from alunite and other non-bauxite ores, and more generally in the overall responsiveness of bauxite demand to higher prices.

The measure economists used for this purpose is the elasticity of demand with respect to own price, or simply the price elasticity of demand. As equation 4 indicates, it is defined as the negative of the partial derivative of demand with respect to own price $(\partial Q_t^d / \partial P_t^o)$ times the ratio of own price to demand (P_t^o / Q_t^d). Since an increase in price normally produces a decrease in demand, this derivative is itself negative, making the price elasticity a positive number.

$$E_{Q_t^d, P_t^o} = - \frac{\partial Q_t^d}{\partial P_t^o} \cdot \frac{P_t^o}{Q_t^d} \tag{4}$$

$$= - \frac{\text{percent change in } Q_t^d}{\text{percent change in } P_t^o} \tag{4a}$$

For those who have forgotten their calculus (or would prefer to), the price elasticity of demand can be easily remembered as the percentage increase in demand resulting from a one percent reduction in price. If the increase in demand is greater than one percent, the elasticity is also greater than one, and we say that demand is elastic. When the elasticity is less than one, demand is inelastic.

Since the derivative of demand with respect to price is equal to the inverse of the slope of the demand curve, where two curves cross, the elasticity of demand will be lower for the curve with the steeper slope. This means that demand at the point where the curves intersect in Figure 2 is more elastic in the very long run, and becomes increasingly less elastic in the long, short, and immediate runs. This, of course, is exactly what we would expect, for consumers have more opportunities to increase or decrease the usage of a material in response to a price change the longer the period they have to adjust.

If the relationship between demand and price is linear, as is assumed in Figure 2 (and earlier in Equation 2), the slope of the demand curve is the same at all points. This means that the price elasticity of demand decreases as one moves down the demand curve, and the ratio price to demand falls. Consequently, other than at their intersection point, we must be careful in comparing the demand elasticities of two curves. The steeper curve will not necessarily have the lower elasticity everywhere.

At times, the relationship between demand and price is assumed to be linear in the logarithms, as in Equation 3 above. In this case, the elasticity does not vary with the level of price and demand; a one percent decrease in price produces the same percentage change in demand over the entire demand curve. The latter, if drawn using logarithmic scales, is a straight line whose slope alone determines the price elasticity of demand. So one can easily compare the elasticities of two curves, even at points where they do not intersect. These properties makes the logarithmic relationship popular in analyzing material demand. However, as stressed earlier, its use is appropriate only if there are good reasons to believe it reflects the true relationship between demand and its determinants.

Up to this point, we have considered only the price elasticity of demand. It is possible to define a separate elasticity for every variable affecting demand, though in practice we normally encounter only two others--the elasticity of demand with respect to the price of substitutes, and the elasticity of demand with respect to income.

The elasticity of demand with respect to the price of a substitute, often called the cross (price) elasticity of demand, measures the percentage increase in demand for a material caused by a one percent increase in the price of a substitute. It too will be larger in the long and very long run than in the immediate and short run, since the opportunities to respond to a change in a substitute's price grow with the adjustment period.

The income elasticity of demand similarly measures the percentage increase in demand caused by a one percent rise in the GDP or some other measure of income. Since the demand for final goods, and in turn the demand for the raw materials needed to produce these goods, responds fully to a change in income rather quickly, the income elasticity does not increase with the adjustment period. There is consequently no need to distinguish among the immediate, short, long, and very long runs, as is the case for own and cross price elasticities.

Another distinction, however, is significant. Earlier we noted that a change in income can be separated into two parts: a cyclical component caused by short term fluctuations in the business cycle, and a secular component caused by long term growth trends. Which of these is primarily responsible for an income change will affect the magnitude of the demand response and the size of the income elasticity.

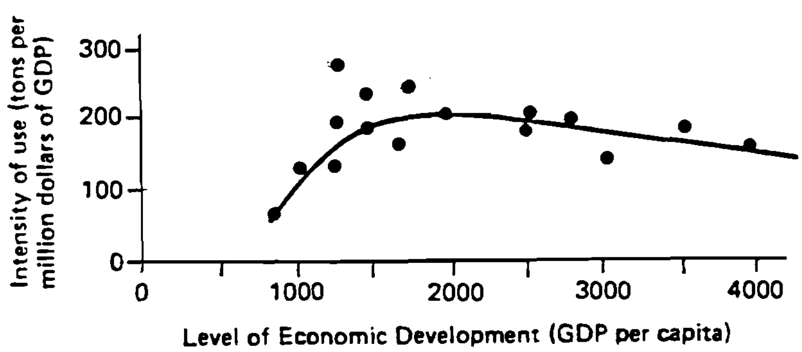
The demand for materials is particularly responsive to income changes caused by business cycle fluctuations. Metals and other materials are consumed primarily in the capital equipment, construction, transportation, and consumer durable sectors of the economy, which use them to produce automobiles, refrigerators, homes and office buildings, new machinery, and other such items. These sectors boom when the economy is doing well, and they suffer severely when it falters. Since small fluctuations in the business cycle cause major changes in their output and in turn the demand for materials, the income elasticity is normally greater than one when the business cycle is responsible for changes in income.

When income changes are the result of secular growth trends, the traditional and still very common presumption is that metal demand grows or declines in direct proportion with income. The income elasticity of demand in such situations is thus one.

In recent years, this assumption has come under attack, in part because the consumption of steel, copper, and other metals has not kept pace with income growth in many countries. This, though, could have nothing to do with rising income. It could simply be the result of technological advances that on one hand permit firms to produce more with the same or less material, and on the other reduce the need for the older and more traditional materials by increasing the variety of new composites, plastics, and other materials available.

Still, as income grows, the desired mix of final goods may also change, affecting material usage and causing the income elasticity of demand to deviate from unity. Indeed, Malenbaum (1975, 1978) and others writing over the last two decades on the intensity of material use provide a rationale for expecting just such a shift.

They contend that countries in early stages of economic development with low per capita incomes are largely agrarian. Their intensity of material use, defined as the amount of material consumed per unit of GDP, is quite low. As such countries begin to industrialize, they invest in basic industry, infrastructure, and other material intensive projects, which cause their intensity of use to rise. As development proceeds, the demand for factories, water and sewer systems, roads, housing, schools, and automobiles is gradually satisfied, and the composition of final production shifts away from manufacturing and construction and toward services. For this and other reasons, they believe the relationship between the intensity of material use and per capita income follows an inverted U-shaped curve similar to that shown in Figure 3 for steel use in the United States.



Notes: GDP is measured in constant (1963) dollars. Points shown in the figure are five year averages, through which a free hand curve has been drawn.
Source: OECD (1974), p. 58

Figure 3. Relationship Between Intensity of Steel Use and Per Capita Income in the United States, 1888-1967

This implies that the income elasticity of demand is greater than one for developing countries operating on the rising portion of the intensity of use curve, and less than one for developed countries on the declining portion, if the rise in income is also accompanied by economic development and higher per capita income. It is possible for income to increase solely as a result of population growth with per capita income remaining stagnant. In this case, the income elasticity of demand is one, as there is no movement along the intensity of use curve and no change in the ratio of material usage to GDP.

Canavan (1983), Landsberg (1976), Radcliffe (1981), Vogely (1976), and others have raised some serious questions regarding the intensity of use hypothesis, though most of the criticisms concern its use for forecasting. The evolution it anticipates as a country develops and per capita income rises in the importance of material intensive goods in overall GDP, while far from proven, certainly seems plausible.

In summary, the income elasticity of demand for metals and other materials depends on several considerations. When the business cycle produces a change in income, the elasticity will normally be greater than unity. When secular growth causes the change in income, the elasticity is likely to be greater than unity only if growth is concentrated in developing countries on the upward sloping portion of their intensity of use curve and if their per capita income is also growing. It will be at or near unity if growth is concentrated in countries at the top of their intensity of use curves or if per capita income is stagnant. Finally, it will be less than unity if growth is concentrated in developed countries on the downward sloping portion of their intensity of use curves and if their per capita income is also growing.

Since the full impact of a change in income is quickly transmitted to the demand for metals and other materials, the income elasticity of demand is the same in the immediate, short, long, and very long run. This is not the case, however, for the elasticity of demand with respect to own price or the price of substitutes. With price changes, the longer the adjustment period, the greater the demand response. Consequently, these elasticities are often less than one in the immediate and short run, and greater than one in the long and very long run.

METAL SUPPLY

Metals come initially from ores extracted from mineral deposits. Some, such as bauxite and most iron ores, contain only one metal worth recovering, and their exploitation results in a single, individual product. Others contain several valuable metals. For instance, molybdenum and gold are often found in porphyry copper deposits, and sulfide nickel mines may produce copper as well.

Where joint production occurs, the resulting metals may be main products, coproducts, or byproducts. A main product is so important to the economic viability of a mine that its price alone determines the mine's output. A byproduct on the other hand is so unimportant, its price has no influence on mine output. When prices of two or more metals affect output, the metals are coproducts.

Once processed and consumed in final goods, metals are often recovered and reused after the final goods come to the end of their useful life and are scrapped. Most of the gold ever mined, for example, is still in use today. The recycling of metals is called secondary production, not because recycled or secondary metals are in some way inferior, but because the original or primary source was a mineral deposit, rather than scrap.

This section examines metal supply. It begins by assuming that all metal supply comes from the primary production of individual products. It then relaxes this assumption, and considers how the recovery of byproducts and coproducts and the production of secondary metal supplement supply.

Individual Products

In examining metal supply, we again want to ignore the multitude of factors whose influence is minor, and concentrate on the few most important variables. Just which variables are worthy of consideration and which can be safely neglected varies with the metal, the source of supply, the time of adjustment, and other factors, and calls for considerable judgment on the part of the analyst. As with demand, the choice is important, and greatly influences the quality of analysis.

While no single list is appropriate for all situations, the following variables are often important determinants of metal supply:

1. Own Price

Firms have an incentive to increase their output up to the point where the costs of producing an additional unit just equals the extra revenue they receive from selling that unit. Consequently, a rise in a metal's price normally increases its supply, while a fall reduces its supply.

In the short run, however, the response of supply to a change in price may be constrained by existing capacity. It takes time to develop new mines and build processing capacity, and so producers may need five to seven years to respond fully to a price increase. An even longer time may be required to adjust fully to a price decrease. Mining and metal processing are capital intensive activities, requiring equipment and facilities with long productive lives. Firms will remain in production, despite a fall in price below average costs, as long as they are recovering their variable or out-of-pocket costs. Only when existing plants and equipment need to be replaced, will they cease production.

2. Input Costs

The costs of labor and other inputs used in metal mining and processing also affect profitability, and in turn metal supply. For example, the rise in world oil prices during the 1970s sharply increased the costs of producing aluminum in Japan. Aluminum smelting consumes large quantities of electric power, and in Japan the needed electricity is generated from oil fired plants. Again, the long lags in adjusting capacity to new conditions mean that the full effect of a change in costs on supply may take a number of years.

3. Technological Change

Advances in technology that reduce the costs of mining or processing also affect metal supply. For example, the mining of copper from large open pit porphyry deposits became feasible in the early years of the 20th century as a result of the introduction of the flotation process for concentrating such low-grade ores. Advances in earth moving capability - more powerful blasting techniques, bigger trucks, and stronger shovels - have since helped keep low-grade deposits economic at constant or even lower real prices. In the future, new technology may augment the supply of cobalt, copper, nickel, and perhaps manganese by permitting the commercial production of these metals from potato shaped nodules lying on the deep ocean floors.

4. Strikes and Other Disruptions

Industry wide strikes have closed down the U.S. copper industry and the Canadian nickel industry for months. Inadequate precipitation in the Pacific Northwest has curtailed hydroelectric power generation, and in turn aluminum production, in that region. Rebel invasions into the Shaba Province of Zaire, the world's largest producer of cobalt, have on several occasions disrupted world supplies of this important metal. Turmoil in neighboring Angola has similarly at times prevented Zairian and Zambian copper from moving over the Benguela railroad to ocean ports and world markets. Strikes, mine accidents, natural disasters, civil disturbances, and other such disruptions can affect the supply of a metal by interrupting either its production or transportation.

5. Government Activities

Government actions influence metal supply in a variety of ways. Environmental regulations and state imposed severance taxes tend to increase costs and reduce supply. Abroad some countries require that mining companies purchase certain supplies from domestic producers, process ores and concentrates domestically, and employ nationals for managerial and technical positions, even though these restrictions may reduce efficiency and increase costs.

Aternatively, governments stimulate metal supply by subsidizing new mines and processing facilities. The United States, for example, provides low interest loans for the purchase of U.S. mining equipment, and offers firms operating abroad insurance against expropriation and other political risk. Almost all governments aid ailing industries, including steel, copper, and other metal firms, to keep them from shutting down.

6. Market Structure

Where a few firms account for most of a metal's production, they may maintain a producer price. As discussed below, this alters the nature of supply.

In addition, over the last thirty years the number and importance of steel owned mining companies have grown. State enterprises now control twenty to forty percent of the bauxite, copper, and iron ore mine output outside the socialist countries (Radetzki, 1983b). In their production and marketing decisions, such firms may be less concerned about the profits and more concerned about maintaining employment, foreign exchange earnings, and other public goals. If so, their market supply is likely to respond less to price signals, particularly low price during market recessions.

The relation between the supply of a metal and its principal determinants, such as those just discussed, is given by the supply function. Normally, it is expressed mathematically. Equation 5, for example, is the function for a metal whose supply (Q_t^s) depends on its price (P_t^o), the wage rate paid by producers (W_t), the cost of energy (E_t), and strikes (S_t). This is a rather simple supply function. It does not consider

$$Q_t^s = g\,(P_t^o, W_t, E_t, S_t) \qquad (5)$$

technological change and certain other variables that often affect supply. It contains no lagged values of the price or cost variables, and hence takes account only of their short run influence. Finally, its exact specification is not indicated.

The relationship between a metal's price and its supply is often of special interest, and is portrayed by the supply curve. The latter shows how much producers will offer to the market place at various prices over a year or some other time period, on the assumption that all other variables affecting supply remain at some specified level.

The supply curve is normally drawn sloping upwards, indicating that supply increases with price. This positive relationship seems plausible for reasons already mentioned, though it can be derived in microeconomics from the theory of the firm.

In special circumstances, however, the curve can over relevant portions be horizontal (implying that sellers are willing to provide the market with as much as they have to offer at a particular price and with nothing below that price), vertical (implying that sellers will provide the market with a given quantity of metal, no more and no less, regardless of the price), or downwards sloping (implying that sellers will offer more to the market the lower the price).

Such behavior can occur for various reasons. Firms may maintain a producer price at which they are prepared to sell all of their available supplies. In other instances, a change in price may not alter the output that maximizes profits for producers. For example, if firms are already operating at full capacity, increasing output in the short run may be extremely (or infinitely) expensive. So even though price rises, firms cannot increase profits by expanding production. Some firms, particularly state enterprises, may also weigh heavily factors other than profits in making their output decisions. These firms may continue to produce at or near capacity, even though it would be more profitable to reduce output, in order to avoid laying off employees. Some may even attempt to increase production at such times if they feel responsible for maintaining their country's foreign exchange earnings.

While such situations do occur, they are unusual. Normally the supply curve is upward sloping, and in this important respect differs from the demand curve. Other characteristics of the supply curve, however, are the same or similar to those discussed for the demand curve.

For example, a movement along the supply curve reflects a change in price, while a shift in the curve itself reflects a change in one of the other determinants of supply. As with demand, a change in price may affect other determinants, and have both a direct and indirect effect on supply. For example, when prices and profits are up, firms are likely to find it more difficult to resist demands from labor for higher wages.

There are also many different supply curves. For refined copper, separate curves are possible for the supply of all producing firms, for the supply of U.S. producing firms, for the supply of Newmont Mining Corporation, for the supply of U.S. exports, for the supply of U.S. imports, for the supply from U.S. government stockpiles, and so on.

Supply reflects how much sellers are willing to offer in the marketplace, and so like demand should not be confused with consumption or production. Where the supply and demand curves intersect, the quantity desired by buyers and the quantity offered by sellers are equal, and at that price the market clears.

As normally drawn, the supply curve assumes that the relationship between price and supply is continuous and reversible. In practice, neither condition always holds. Some mines and smelters operate on a very large scale. When they begin or stop production, supply experiences a discrete jump. Similarly, when price goes up, it may induce higher wages, shifting the supply curve to the left, which makes it impossible to move back down the original curve. Alternatively, higher prices may stimulate new technology and lower costs, causing the supply curve to shift to the right. In this situation, should price return to its initial level, supply would be greater not less than originally.

The supply curve also assumes that metal producers have a certain amount of time to adjust to changes in price, input costs, and other determinants. Here, as with demand, it is useful to distinguish four adjustment periods and in turn four types of supply curves - the immediate, short, long, and very long run.

In the *immediate run*, firms do not have time to alter their rate of production. Consequently, supply cannot exceed current output plus available producer inventories or stocks. This does not mean, however, that producers must provide to the marketplace all of their output. If demand is weak, they can build up inventories for sale at a later time when market conditions have improved. So the immediate run supply curve is not everywhere vertical or nearly vertical, as we might first think.

Before assessing the general shape of the immediate run supply curve, we need to distinguish two types of metal markets, producer markets and competitive markets, for the supply curve is different for each. Firms in producer markets quote the price at which they are prepared to sell their product. These markets, normally characterized by a few major sellers, have relatively stable prices, though when demand is weak, actual prices may fall below quoted producer prices as a result of discounting and other concessions. Steel, aluminum, nickel, and magnesium are a few of the metals sold in producer markets.

In competitive markets, price is determined by the interplay of supply and demand, and is free to fluctuate as much as necessary to clear the marketplace. Many buyers and sellers are typically active in competitive markets, and price is often set on a commodity exchange, such as the London Metal Exchange (LME) or the New York Commodity Exchange (Comex). Tungsten, manganese, and silver are metals sold in competitive markets.[2]

Producers are price takers in competitive markets, and have no influence over the going market price. Nevertheless, they still control their own supply. While reducing output is not feasible in the immediate run,[3] they need not, as pointed out above, supply what they produce to the marketplace. Alternatively, when prices are high and likely to fall in the future, firms may supply some of their available inventories in addition to current production.

An immediate run supply curve for producers selling in a competitive market is shown in Figure 4a. At very low prices, it indicates that little or no supply is forthcoming as production is withheld from the market in anticipation of higher prices in the future. As price rises, supply expands, first modestly and then substantially as more and more of current production is placed on the market. Further increases in supply must at some point come from inventories. Since producers will deplete their stocks only at high prices, and since stocks can normally augment supply by only modest amounts compared to current output, the supply curve shown in Figure 4a becomes quite steep at high prices, and eventu-

[2]For many years copper was unusual in that the major firms in North America maintained a producer price, while elsewhere the producers sold at prices closely tied to the competitive LME copper market. At times, the U.S. producer price would deviate considerably from the LME price, causing economists and others (for example, see McNichol, 1975) to ponder how this was possible given the ease of shipping copper to and from North America. In the late 1970s, however, many North American producers began selling their copper on the basis of the Comex price, which closely parallels the LME price. Others changed their quoted prices so frequently in response to fluctuations in the Comex price that a producer price in fact ceased to exist.

[3]It is, of course, always possible for firms even in the immediate run to reduce or stop production. Management can simply close down operations. This, however, is not a feasible or reasonable option in the immediate run, because labor and possibly other variable inputs require some notice before they can be laid off. So in the immediate run even variable inputs are to some extent fixed. In addition, firms will often want to finish goods in the process of being produced, since they already have an investment in these goods.

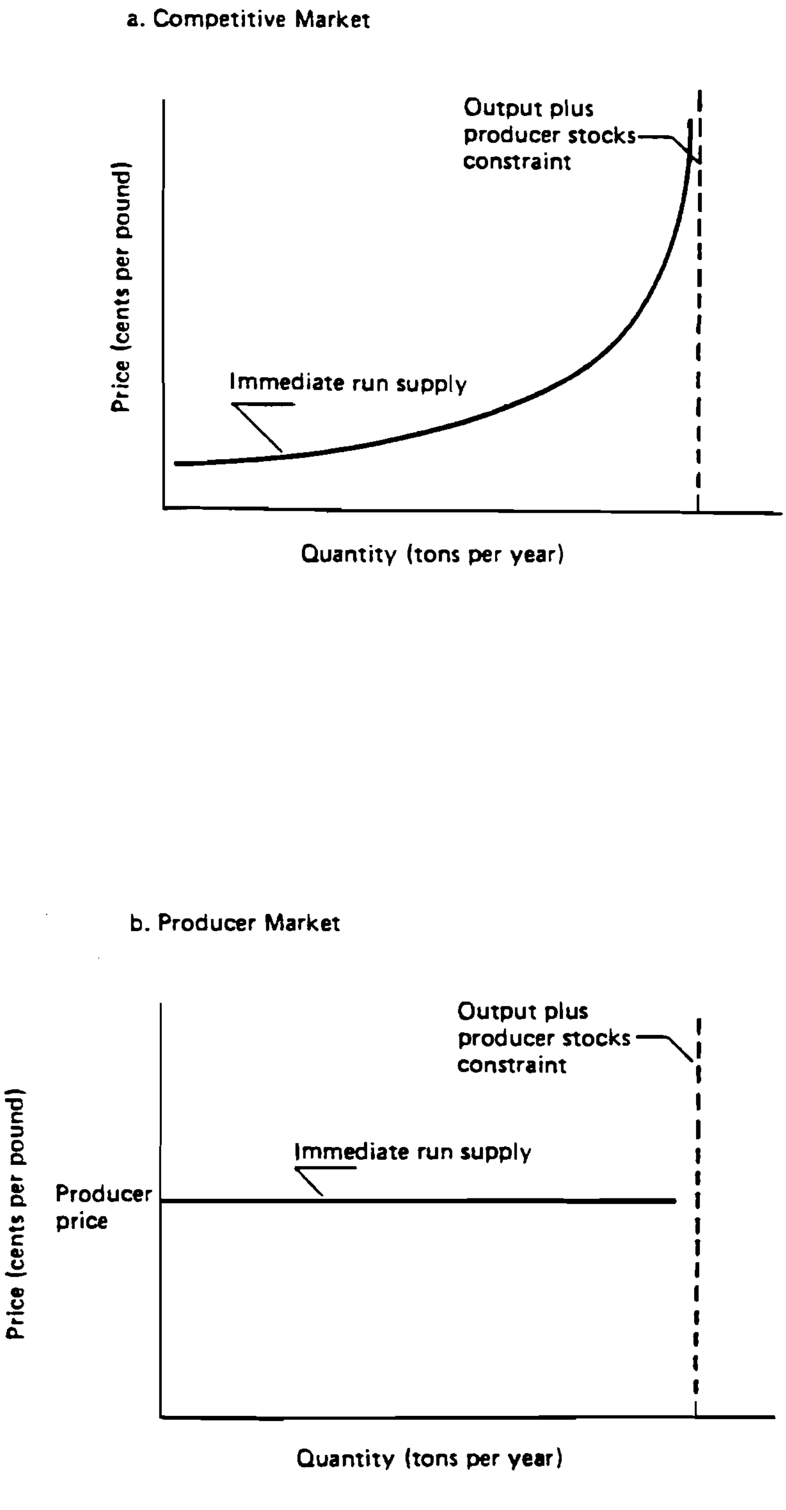


Figure 4. Supply Curves in the Immediate Run

ally vertical. As the curve approaches the constraint imposed by current production plus producer stocks, firms are unwilling or unable to add further to supply by drawing down inventories.

An immediate run supply curve for a producer market is illustrated in Figure 4b. It is simply a horizontal line at the producer price that extends from zero to an amount equal to current production plus the stocks producers are willing to sell. Since firms can not increase their output in the immediate run, current production plus available producer stocks impose a constraint on supply. Figure 4b shows the curve stopping slightly before this barrier, as producers usually are not willing to sell all their available stocks.

The supply curve in Figure 4b assumes that firms faithfully adhere to the producer price. If this is not the case, if some or all firms discount the producer price at times of weak demand, the curve is not perfectly horizontal, but instead drops somewhat at lower quantities reflecting these price concessions.

The curves shown in Figure 4 indicate that in both competitive and producer markets metal supply is quite responsive to price until supply approaches current output plus producer stocks. At this point higher prices attract little or no additional supply into the market.

To assess the responsiveness of supply to price, economists use the elasticity of supply, defined as the partial derivative of supply with respect to price ($\partial Q_t^s / \partial P_t^o$) times the ratio of price to supply (P_t^o / Q_t^s). This measure reflects the percentage increase in supply produced by a one percent rise in price.

$$E_{Q_t^s, P_t^o} = \frac{\partial Q_t^s}{\partial P_t^o} \cdot \frac{P_t^o}{Q_t^s} \tag{6}$$

$$= \frac{\text{percent change in } Q_t^s}{\text{percent change in } P_t^o} \tag{6a}$$

We say that supply is elastic when the elasticity is greater than one, and inelastic when it is less than one. Where the supply curve is vertical, (as on the right side of Figure 4a) or where it simply ends (as on the right side of Figure 4b), supply is completely unresponsive to price and the supply elasticity is zero. Where the supply curve is flat or horizontal, supply is highly or infinitely responsive to price and the elasticity is very large.

In the *short run*, producers have time to change their output but not capacity. So the supply curve is constrained by existing capacity rather than current production. If the industry is not operating at full capacity, this means the supply curves shown in Figure 4 for both producer and competitive markets are extended in the short run by the amount of available idle capacity.

In the *long run*, new mines can be developed, and processing facilities built. Firms can also expand the capacity of existing operations. Consequently, the relatively flat or elastic portions of the supply curve encompass far more output than in the immediate or short runs. Only after all known deposits of a metal are in operation does the supply curve stop or become vertical.

In the *very long run*, even the constraint imposed by existing known metal deposits no longer holds, as firms have the time to conduct exploration and find new deposits. New technology induced by the exhaustion of know deposits and higher metal prices may also permit the exploitation of new types of deposits. Concern over the depletion of the high grade iron ore in northern Minnesota after World War II, for example, led to new techniques permitting the mining of taconite, a lower grade but abundant iron bearing mineral. This greatly increased the number of iron ore deposits in Minnesota and elsewhere.

So in the very long run no barrier or constraint forces the supply curve to terminate or become vertical.[4] Consequently, the very long run supply curve, in contrast to the other supply curves we have considered, may be relatively flat or elastic over its entirety with no terminal point. In fact, for a number of metals sold in competitive markets, it may become more elastic at higher prices and quantities, because more costly sources of supply or deposit types are found in greater numbers and contain on average more metal. Large porphyry copper deposits containing about four-tenths of a percent copper, for example, are fairly abundant and easy to find. Should the price of copper reach the level needed to make such deposits attractive, supply would expand greatly. A similar situation exists with iron ore and taconite deposits, with nickel and laterite deposits, and with aluminum and non-bauxite ores.

The major differences just discussed among the four time-related supply curves are highlighted in Figure 5a for competitive markets and in Figure 5b for producer markets. It is particularly important to notice

[4] It is true that the earth is finite, and so the amount of copper and other metals it contains is fixed. But the quantity of every metal found in the earth's crust compared to the amount supplied ***annually*** (which is what the supply curve relates to price) is so enormous (Tilton, 1977) that this ultimate constraint simply is not relevant.

how the supply curves in both types of markets expand over increasingly greater quantities as the time permitted for adjustment increases, allowing one after another of the constraints on supply to be overcome. In the very long run, there are no relevant constraints, and supply remains elastic over the entire range of plausible outputs.

The relative vertical positions of the curves shown in Figure 5 are based on certain presumptions about the influence of production costs on supply. In the case of producer markets, for example, we assume the producer price (which determines the height of the supply curve) is set on the basis of average total production costs at a standard or representative level of capacity utilization. These costs are likely to be similar in the immediate and short run, since capacity is fixed. In the long run, as new and presumably higher cost deposits are brought into production, average total costs will probably rise. In the very long run, though, new discoveries and the exploitation of new types of deposits should keep average total costs below those of the long run. Consequently, in Figure 5b the immediate and short run supply curves are drawn at about the same height, the very long curve somewhat higher, and the long run curve even higher.

Unfortunately, we still have much to learn about how producer prices are set, and the extent to which they are actually tied to production costs. While average total costs may often be the major determinant, there are presumably instances when this is not so, and when other factors are important. So the relative heights of the curves in Figure 5b should be considered simply as plausible and illustrative.

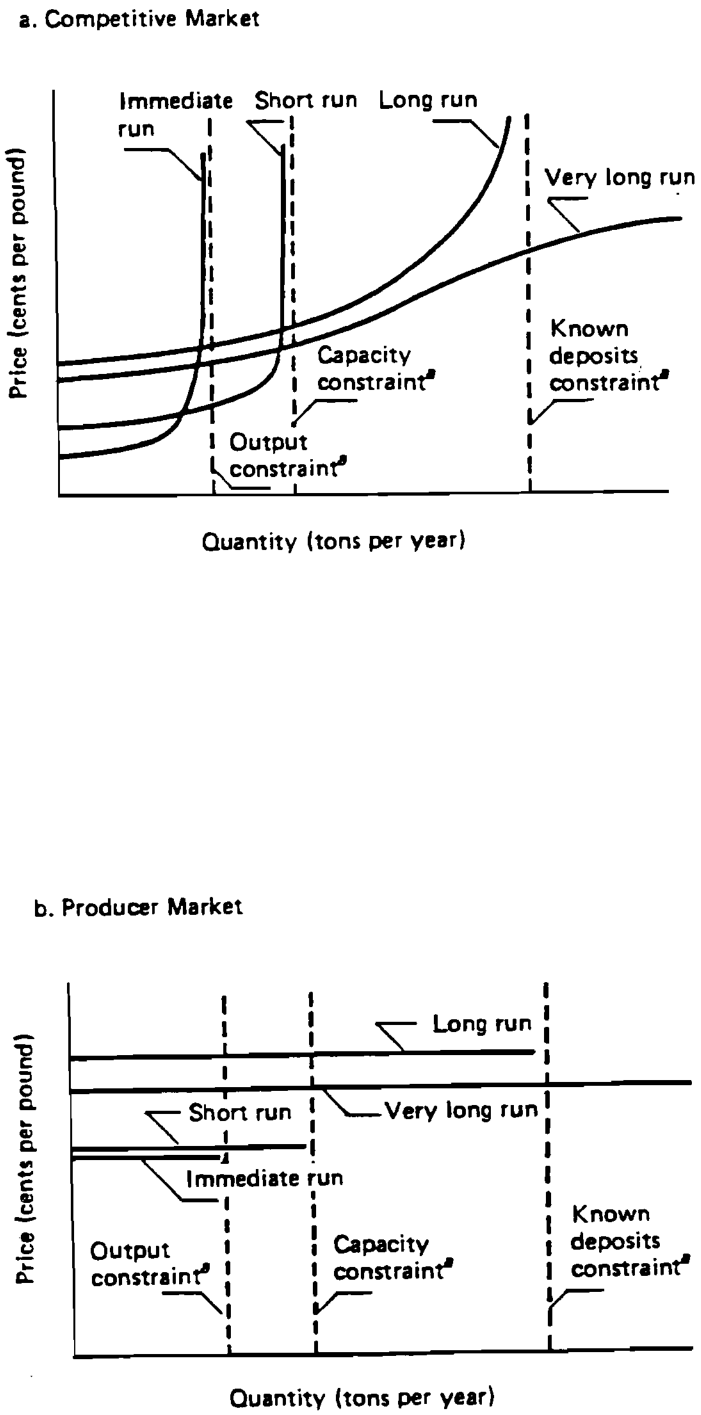


Figure 5. Supply Curves in the Immediate, Short, Long, and Very Long Run

For competitive markets, the immediate run supply curve is drawn below the short run curve in Figure 5a until output approaches the output constraint. Firms have two options available in the short run for reducing their supply--they can cut production in addition to building up inventories--and so are more likely to supply less at any particular price when demand is low.

The short run curve, in turn, lies below the long run curve until output approaches the capacity constraint. This is because firms in the short run, in contrast to the long run, have an incentive to continue production when price is below their average total costs so long as they are recovering out-of-pocket or average variable costs.

The long run curve in Figure 5a is also shown above the very long run curve, for in the very long run the discovery of low-cost deposits and the development of new deposit types should reduce costs and in turn the price required to elicit any level of supply.

Economists have much more to say about the relationship between prices and costs in competitive markets, than in producer markets. In the short run, according to microeconomic theory, competitive firms will have, as pointed out earlier, an incentive to produce and supply a commodity as long as price covers average variable costs. Since variable costs do not include the costs of capital and other fixed inputs, in the short run firms may remain in production even though they are losing money. This is because fixed costs must be paid whether a firm produces or not, and so losses are minimized by staying in business as long as price is above variable costs.

This suggests that one might estimate the short run supply curve for a metal sold in a competitive market by determining the average variable costs and capacity associated with each operating mine. This information can then be arranged as in Figure 6, so that mine A with the lowest average variable costs (OC_a) and capacity (OQ_a) is shown first, mine B with the second lowest variable costs (OC_b) and capacity ($Q_a Q_b$) next, and so on. The resulting curve traces out a short run supply curve. It approximates the short run marginal cost curve for the industry, and shows how costs increase as the industry expands output by bringing back into operation mines with increasingly higher production costs.

While this procedure is used by mineral firms and others, and can provide useful insights into the nature of the short run supply curve, it is predicated on several assumptions. All producers must have similar shutdown and start up costs, and share similar views regarding future price movements. Otherwise, some mines may remain operating while lower cost competitors shut down because they have higher shut down and start up costs, or because their managers anticipate a rapid recovery of prices. In addition, governments must not provide subsidies or other public assistance when prices decline to keep marginal mines from closing. And, all producers must be primarily interested in maximizing profits. In practice, of course, these conditions may not be met. State owned enterprises in foreign countries, for example, may remain in production even when the market price drops below their variable costs because employment and foreign exchange earnings are more important than profits. When this is the case, the actual short run supply curve lies below that shown in Figure 6.

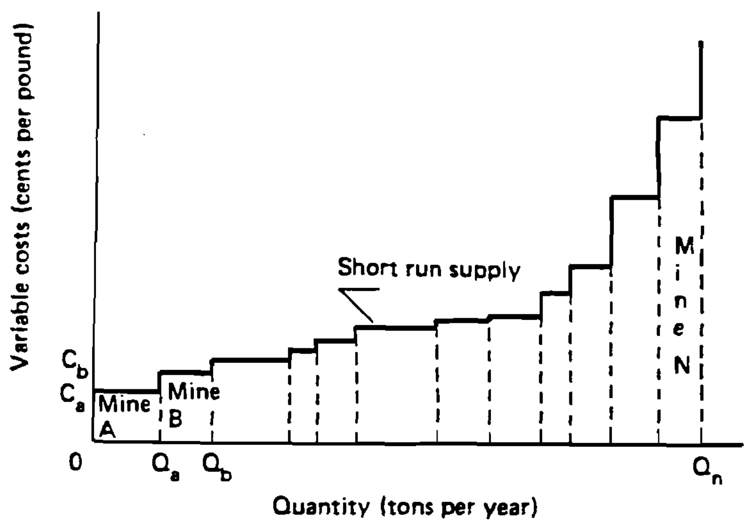


Figure 6. Short Run Supply Curve Derived From Capacity and Variable Cost Data

Long run supply curves for metals sold in competitive markets can also be estimated using a similar procedure. The U.S. Bureau of Mines (Bennett, 1973; Babitzke, 1982) and others have calculated the average total costs, including a competitive rate of return on invested capital, associated with all known deposits and their annual production capacity for copper and other metals. With this information, the industry's long run supply is approximated in a manner similar to that illustrated in Figure 6. Though, of course, the long run supply curve is derived from average total costs, not average variable costs, and must take account of all known deposits, including those that have not yet been placed into production.

Again, this approach can provide useful insights into the nature of supply, but it does presume that undeveloped deposits will be brought into operation in order of their average total costs, and only after price rises to a level that covers these costs. In practice, this is not always so. Some deposits come on stream sooner, because host governments are willing to provide expensive infrastructure and in other ways subsidize their development. On the other hand, political risk, heavy taxation, and other adverse public policies may delay the development of other deposits.

Byproducts and Coproducts

So far we have taken account of only the primary supply of individual products. Often, however, two or more metals are recovered from the same mine and ore body. For example, gold, silver, platinum, molybdenum, selenium, and a number of other metals are at times contained in copper ores. On the other hand, copper is recovered in substantial quantities from the major sulfide nickel deposits in Canada and elsewhere. Similarly, lead and zinc are often found and mined together.

In such instances, as pointed out earlier, we can distinguish metals mined as main products, coproducts, and byproducts. A main product is by definition so important that it alone determines the economic viability of a mine. Its price is the only metal price affecting the mine's output of ore and main product. When two metals must be produced to make a mine economic, both influence output, and they are coproducts. A byproduct is produced in association with a main product or with coproducts. Its price has no influence over the mine's ore output, though normally as we will see, it does affect byproduct production.

Main product supply is quite similar to that for individual products discussed in the previous section, and so is not considered further here. Instead, this section, drawing heavily on Brooks (1965), highlights the differences between the supply of byproducts and coproducts on the one hand and the supply of individual products on the other.

Before proceeding, however, we should point out that some metals, such as gold, silver, and molybdenum, are main products at some mines, coproducts at other mines, and byproducts at still other mines. To determine the total primary supply for such metals, one needs to assess main product, byproduct, and coproduct supply and then add them together. Moreover, gold and other metals may at some mines be a byproduct at times, and a coproduct or even main product at other times, if the price of gold and associated metals vary greatly.

1. Byproduct Supply

There are two important differences between the supply of byproducts and the supply of individual or main products. The first is that byproduct supply is limited by the output of the main product. The amount of molybdenum recoverable as a byproduct of copper production, for instance, can not exceed the physical quantity of molybdenum actually in copper ore. As production approaches this constraint, the byproduct supply curve turns upward and becomes vertical. This is because a higher byproduct price does not increase the output of ore or of main product. Otherwise, it would not be a byproduct. So at some output, supply even in the very long run becomes unresponsive or inelastic to further increases in byproduct price.

This characteristic of byproduct supply is illustrated in Figure 7. Both the long and very long run supply curves, which are shown as the same curve in Figure 7, are quite elastic with respect to price until output approaches the byproduct constraint, which is imposed by main product output. Thereafter, little or no increase in supply is possible, as most of the byproduct contained in the available ore has been recovered. Since normally byproduct producers are competitive firms, in the sense that they have no control over market prices, Figure 7 shows the byproduct supply curve for only the competitive market. The same constraint, however, would apply in a producer market, causing the supply curve to end as output approached the amount of byproduct contained in the available ore.

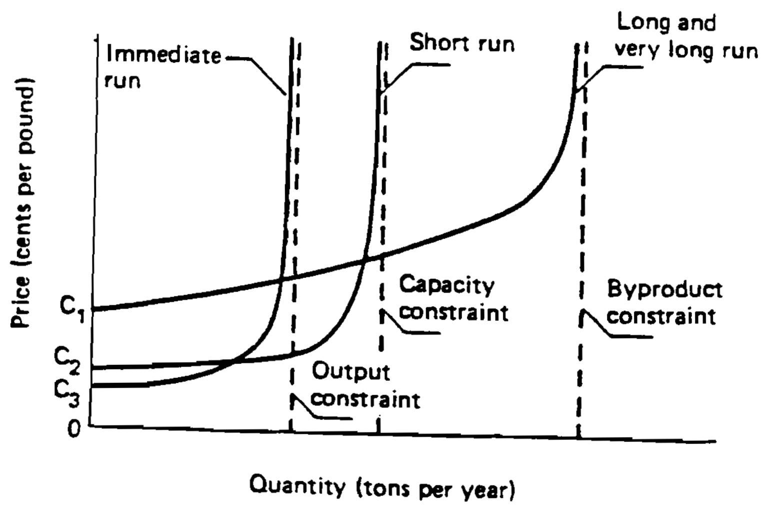


Figure 7. Supply Curves for Byproduct Metal in a Competitive Market

Since it is the price of the main product, rather than the byproduct, that stimulates supply in the very long run through exploration and the development of new technologies for exploiting alternative ores, the long and very long run byproduct supply curves may actually be the same, as shown in Figure 7. This, however, need not be the case. A high byproduct price, for example, may encourage new technology that allows a greater recovery of the byproduct contained in the main product ore. In this case, the byproduct constraint becomes binding at a greater output in the very long run, causing the long and very long run byproduct supply curves to deviate from each other.

The constraint imposed by main product output shifts in response to changes in main product demand and supply. If the demand for copper goes up, for example, this causes the price and output of main product copper to rise, increasing the amount of ore from which byproduct molybdenum can be recovered. For this reason, the supply function of a byproduct contains the output (or price) of the main product, in addition to its own price and the other important supply variables discussed earlier. Since changes in main product output are independent of the byproduct price, they reflect a shift in the byproduct curve itself, rather than a movement along it.

While the output of the main product places an upper limit on byproduct supply, this limit may not be binding in the immediate and short run. Main product ores may contain more of the byproduct than is needed or demanded. In this situation, the equipment and other facilities required for byproduct processing may be insufficient to treat all the available ore, so that capacity rather than main product output limits byproduct supply. This constraint, however, applies only in the immediate and short runs, as new capacity can be installed in the long run. Such a situation, where capacity rather than main product production limits byproduct supply in the immediate and short runs is illustrated in Figure 7. The immediate run supply curve in Figure 7 is further constrained by current output (plus available producer stocks), implying that the industry is not operating at full capacity. Otherwise, the output and capacity constraints would be the same, and the immediate and short run curves would both become inelastic at about the same output.

There is, as noted earlier, a second important difference between byproduct and individual (or main) product supply, namely, that only costs specific to byproduct production affect byproduct supply. Joint costs, those necessary for the production of both the main product and the byproduct, are borne entirely by the main product, and do not influence byproduct supply.

This means that byproduct supply curves for competitive markets, such as those drawn in Figure 7, reflect the marginal costs of byproduct production exclusive of all joint costs. As a result, byproduct supply until production approaches the constraint imposed by main product output is often, though not always, available at a lower price than the same metal from main or individual product supply.

Since joint costs are borne by the main product, it is sometimes assumed that byproducts are basically free goods, and that the byproduct supply curve is simply a vertical line at that output reflecting the amount of byproduct in the main product ore. For this to be true, however, two conditions must be satisfied: the production of the main product must require the separation of the byproduct, and no further processing of the byproduct must be necessary after separation. Only if both of these conditions are met are all byproduct costs joint, and so attributable to the main product. In practice, the first condition often is satisfied. Though there are exceptions; for example, in some end uses the separation of antimony from lead is not necessary. Still, it is the second condition that normally gives rise to specific byproduct costs. Antimony, molybdenum, gold, silver, and other byproducts require further upgrading and processing after separation from the main product before they can be sold on commodity markets or used in the production of other goods.

The existence of specific costs means that byproducts are not free, and that they will not be recovered and supplied to the market unless their price covers these costs. In Figure 7, the lowest cost byproduct producer has specific costs equal to OC_1 cents per pound. Once byproduct capacity is in place, the market price can fall below specific costs and production will continue in the short run, as long as price covers the minium variable or out of pocket costs specific to byproduct production (OC_2). In the immediate run, the price can even decline further (OC_3). Over the long run, however, capacity will not be replaced and byproduct production will cease if price remains below the minimum specific cost (OC_1).

Since byproduct production tends to occur first where main product ores are particularly rich in the byproduct metal or are for other reasons less costly to process, the marginal costs specific to byproduct production usually rise with output. For this reason, the long (and very long run) supply curve shown in Figure 7 has an upward slope over its relatively flat or elastic segment.

2. Coproduct Supply

Coproducts are in many respects between byproducts and main products. Their price influences mine output, but so do the prices of associated coproducts. Joint production costs must be shared, as no single coproduct can support them alone. This means that a coproduct's price must cover its specific production costs plus some but not all of joint costs.

Consequently, a coproduct's supply function includes its own price, the price of other coproducts, its specific costs, and joint costs, as well as possibly other factors. A change in any of these supply determinants, other than own price, causes a shift in the supply curve. An increase in specific or joint costs, for example, shifts the curve upward, while an increase in the price of an associated coproduct shifts it downwards.

Coproduct supply curves have the same general shape as those illustrated for individual products in Figure 5. In the immediate, short, and long runs, coproduct supply is similarly constrained by current output, capacity, and known deposits. Since a coproduct must bear only a part of joint production costs, supply may be available at lower costs than from main or individual product output. This reduces the height of the supply curve in competitive markets, and possibly in producer markets as well. In addition, the long run supply curve until the capacity constraint is approached and the very long supply curve have a tendency to become more elastic or flatter as the coproduct's price increases. This is because a one percent increase in the coproduct's price produces a greater increase in overall mine revenues, and hence the incentive to develop additional supply, the higher the coproduct's price is initially.

Secondary Production

Secondary production adds to the supply of metals by recycling new and old scrap. New scrap is generated in the manufacturing of new goods. When the telephone company installs the phone lines for a new apartment building, a certain amount of copper wire scrap results. The skeleton that remains after the round tops for soft drink cans are stamped from a rectangular sheet of aluminum is also part of the supply of new metal scrap.

Old scrap comprises those consumer and producer goods that have come to the end of their useful lives. They are obsolete, worn out, or for some other reason no longer of use. When an apartment building is torn down, its phone lines are recovered and added to the supply of old copper scrap. An empty soft drink can is also part of old scrap supply.

Secondary production is an important source of total supply for many but not all metals. In recent years, the recycling of old scrap alone has accounted for about 20 percent of U.S. aluminum consumption, 30 percent of U.S. copper consumption, and 50 percent of U.S. lead consumption. On the other hand, little or no beryllium, columbium, or germanium is recovered from old scrap. These metals are dissipated when used or for other reasons are too costly to recycle.

Secondary metal supply differs in several respects from primary metal supply, particularly that for individual or main products. For example, secondary producers are for the most part highly competitive, and rarely support a producer price. So in considering secondary supply, we need not be concerned with supply curves for a producer market.

In addition, it is the availability of scrap, rather than the availability of known deposits, that limits secondary supply in the long run. Since the important factors determining the availability of new and old scrap differ, secondary supply from these two sources are best considered separately.

1. Secondary Supply from New Scrap

The amount of new scrap available for recycling depends on three factors - current overall metal consumption, the distribution of this consumption by end uses, and the percentage of consumption resulting in new scrap for each end use. A rise in overall copper consumption, due to an increase in GNP or a change in consumer preferences, increases the availability of new copper scrap, causing both the constraint and the long run supply curve for secondary copper metal produced from new scrap to shift to the right. On the other hand, improved manufacturing techniques that reduce the percentage of copper scrap generated in the manufacturing of electric wire or other fabricated products shifts the constraint and the curve to the left. A change in the allocation of copper so that more goes into goods whose production results in little scrap will also tend to shift the constraint and the curve to the left.

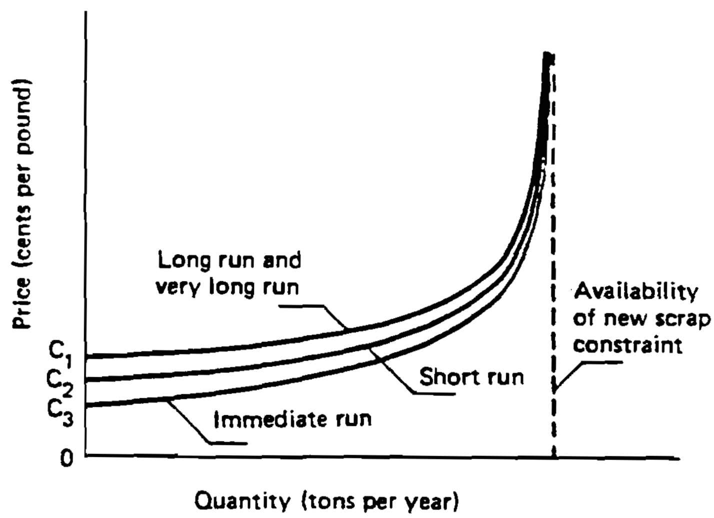


Figure 8. Supply Curves for Secondary Metal From New Scrap in a Competitive Market

This means that the supply function for secondary metal from scrap, in addition to technological change and other determinants discussed earlier, should include a variable for the availability of new scrap. Often metal consumption is used as a proxy for the availability of new scrap. This is appropriate, however, only if its distribution by end uses and the porportion of consumption resulting in new scrap for each end use remain unchanged. Otherwise, these variables as well belong in the supply function.

The shape of the long run (and very long run) supply curve for secondary metal from new scrap is shown in Figure 8, and reflects the cost of collecting, identifying, and processing new scrap. The scrap which is the least costly to recycle will be processed first. These costs, given in Figure 8 as OC_1 cents per pound, determine the point where the curve intersects the vertical axis. As most new scrap is relatively inexpensive to recycle, the slope of the curve rises from this point very gently over the range of possible outputs. Only as the constraint imposed by the availability of new scrap is approached does the supply curve turn upward.

The low cost of recycling new scrap compared to alternative sources of supply means all or almost all new scrap is recycled. So over the range of normal prices little additional supply from new secondary is possible, making supply price inelastic. However, at very low prices, those approaching the cost of recycling new scrap, supply is as Figure 8 illustrates, quite elastic with respect to price.

The fact that almost all new scrap is recycled means that the constraints limiting supply in the immediate and short run, namely output and capacity, are not likely to differ significantly from the constraint in the long run imposed by the availability of new scrap. So although the immediate and short run curves lie below the long run curve, they turn upward and become vertical at about the same output.

If current technology allows the full recovery of the metal content of new scrap, the very long run supply curve is also constrained by the availability of new scrap. In this case, it and the long run curve coincide, as illustrated in Figure 8. If this is not the case, if a high metal price induces over the very long run new technology that allows more metal to be recovered from the available scrap, the constraint on supply would be further to the right in the very long run. It would, however, not be eliminated. At some output the supply of secondary metal from new scrap, like that for byproduct supply, becomes inelastic to price even in the very long run, and in this regard differs from the supply of independent and main metal products.

2. Secondary Supply from Old Scrap

The availability of old scrap during any particular year depends on (a) the *flow* of metal containing products reaching the end of their service life during the year, and (b) the *stock* of metal containing products no longer in use or service at the beginning of the year, but which have not yet been recycled. The number of old automobiles available for recycling, for example, includes those scrapped during the year as well as those scrapped in earlier years but which for one reason or another have yet to be recycled. Some are rusting away in their owners' backyards, others have been abandoned in remote areas.

The flow of old metal scrap depends on the number and types of goods in use throughout the economy at the beginning of the year, their metal composition, their age distribution, the mean age at which they come to the end of their service life, and the frequency distribution around this mean. Since these factors together determine the flow of old scrap, they can be included in the supply function for secondary metal produced from old scrap in place of the latter.

The stock of old metal scrap depends on the accumulated past flows of products coming to the end of their service life. From this total, the quantities already recovered through recycling must be subtracted. This means that over time the stock of old scrap will grow if the amount recycled is less than the incoming flow.

Even though it depends on two flow variables--the accumulated flow of old scrap and the accumulated recycling of this scrap in the past--the stock of old scrap is as stated a stock and not a flow. Consequently, what is recycled this year is not available for recycling in the future. This has several important implications, and makes it necessary to distinguish between the supply of secondary metal produced from the flow and from the stock of old scrap.

A long run supply curve for the former is shown illustrated in Figure 9a. At the price P_1, this curve indicates that the quantity q_1 of the secondary metal is recovered from the incoming flow of old scrap. The remainder of the incoming flow of old scrap is not recycled, but rather added to the stock of old scrap available for recycling in the future.

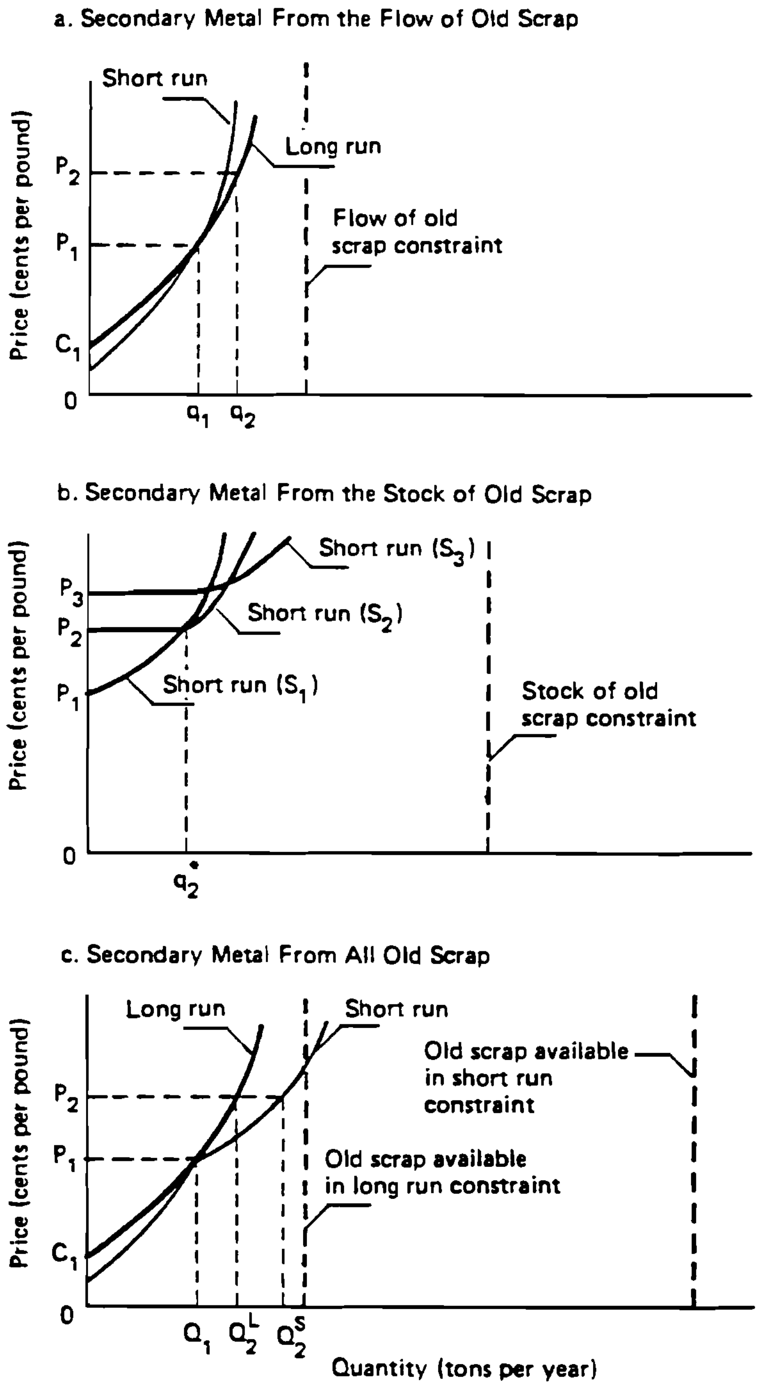


Figure 9. Supply Curves for Secondary Metal From Old Scrap in a Com-

The curve begins at the vertical axis at a fairly low price, reflecting the fact that some old scrap is of very high quality. It can be recycled at a relatively low cost (OC_1) per pound of contained metal. However, in contrast with new scrap, costs rise notably as more and more of the old scrap flow is recycled. This is because some scrap is scattered geographically, and so collection costs are high. Some of it is a mixture of various scrap types, requiring expensive identification and sorting techniques. Some of it is highly contaminated with rubber, glass, wood, and other waste material, making treatment costs high. Indeed, in some uses, such as lead in gasoline, the metal is so dissipated after use that recycling is simply too costly to contemplate. It is for such reasons that much of the old scrap flow is not recycled for many metals.

Figure 9a also illustrates a short run supply curve for secondary metal produced from the flow of old scrap. This curve is drawn beneath the long run curve at prices below P_1, on the assumption that secondary producers will continue to operate and supply the market in the short run as long as they can cover variable costs. Since fixed costs tend to account for a relatively small share of total production costs, particularly in comparison with primary production, the short run curve lies relatively close to the long run curve.

At prices higher than P_1, Figure 9a shows the short run curve above the long run curve, implying that producers take advantage of capacity constraints in the short run to realize higher prices and profits. However, capacity tends to be more flexible in secondary compared to primary production. It is easier to increase output by increasing the number of shifts and by augmenting labor in other ways. For this reason, the short run supply curve above the price P_1 is drawn quite close to the long run curve.

This, though, need not necessarily be the case. Under certain circumstances, the short and long run curves may lie quite far apart. For example, at particularly high metal prices, certain products that account for a significant part of the total old scrap flow may become economic to recycle. The capacity to handle these products, however, may not exist, causing the short run supply curve to become vertical considerably before the long run curve.

Conversely, short run supply can exceed long run supply at relatively high prices, with the reverse being true at low prices, as a result of the "accelerated scraping" phenomenon. The latter occurs when products close to the end of their service life are scrapped earlier than they otherwise would be as a result of high metal prices. For example, when machines become old and obsolete, they are at times held in reserve, and used only occasionally during peak production periods. Eventually, they may be kept for emergencies, for example when newer equipment fails. In some cases, they are stored away, and cannabilized for their parts. High metal scrap prices encourage the premature recycling of such equipment. Conversely, when metal prices are particularly low, the costs of keeping such equipment in terms of the scrap revenues forgone are quite modest, which may prolong the period before they are eventually scrapped. This implies that in some circumstances the constraint imposed by the flow of old scrap may not be invariant in the short run to price, but rather may increase with price at least over a range.

So far we have focussed our attention entirely on secondary supply from the flow of old scrap. Figure 9b illustrates three short run secondary supply curves from the stock of old scrap. The first curve S_1 indicates that at the price P_1 no metal is recovered from the stock of old scrap. This price simply does not cover recycling costs. At higher prices, however, some of the available old scrap stock can be economically processed. At P_2, for example, the old scrap stock will produce an amount of metal equal to q_2^*.

Over the long run, however, this output is not sustainable, because the old scrap stock recoverable at costs under P_2 is depleted. So if price remains at P_2, the short run curve soon becomes truncated in a manner similar to that illustrated by the curve S_2. Above price P_2 this curve lies somewhat to the right of the original curve, reflecting the fact that the flow of old metal scrap with recycling costs above P_2 has not over the intervening years been recycled but rather added to the stock of old scrap. Below price P_2, however, the new supply curve S_2 indicates that no supply from the stock of old scrap is now forthcoming, as the material that can be recycled economically at this price has been exhausted. Similarly, if the price rises to P_3, the short run supply curve will soon approach the shape indicated by the S_3. This means that normally there exists no long run supply curve for secondary metal from the stock of old scrap.[5]

[5]It is possible that at very high prices large reservoirs of old scrap may become economical to process. For example, at some price certain metals found in dumps and landfills could presumably be extracted profitably. In such instances, the depletion of the available stock of old scrap could take a number of years, and make a long run supply curve possible.

Although the size of the stock of old scrap does impose a constraint on the ultimate supply of secondary metal from this source of scrap, this constraint is not nearly as binding as is the availability of scrap in the case of supply from the flow of old scrap or from new scrap. Long before the stock of old scrap is exhausted, processing is constrained by high costs. Most of the available old scrap stock has not been recycled precisely because at prevailing prices it has been uneconomical to do so. Other sources of supply--individual product, main product, coproduct, byproduct, secondary from new scrap, and secondary from the flow of old scrap--for the most part have been cheaper.

It is also worth noting that the short run secondary supply curve from the stock of old scrap depends over time on the market price and the short run supply curve for old scrap flows. If price falls below P_1, some of the incoming flow of scrap with recovery costs below P_1 will not be recycled. Rather it will be added to the stock of old scrap, shifting the short run secondary supply curve from the stock of old scrap (S_1) downward as well as to the right over time. Alternatively, if the market price remains at P_1, the curve S_1 shifts to the right, but not downward. If price rises above P_1, as explained earlier, the curve S_1 moves to the right at prices above the prevailing market price. While below this price, the curve moves to the left as the scrap with processing costs below the market price is recycled. This continues until the supply curve intersects the vertical axis at the prevailing market price.

As Figure 9c illustrates, the secondary supply curve from all old scrap can be derived by combining, or more precisely by adding horizontally, the secondary supply curve for the old scrap flow and for old scrap stocks. The long run curve is simply that for secondary from the old scrap flow shown in Figure 9a, as there is no long run secondary supply curve from the stock of old scrap.

The short run curve is derived by adding the appropriate short run curve for the stock of old scrap, assumed to be the curve S_1 in Figure 9b, to the short run curve for the flow of old scrap. Since the short run curve for the stock of old scrap intersects the vertical axis at P_1, implying that below this price no secondary metal from old scrap stocks is forthcoming, the short run secondary curve for all old scrap below this price is simply the short run curve for the flow of old scrap.

Figure 9c highlights two interesting facets of secondary supply from old scrap. First, the constraint posed by the availability of scrap is actually less binding in the short run than in the long run. This, of course, is because the stock of old scrap, if exploited in the short run, is not available in the long run.

Second, an increase in price, for example from P_1 to P_2, may actually produce an increase in supply that is greater in the short run than the long run. In the short run, some of the stock of old scrap may be recycled, adding to supply. It is presumably for this reason that efforts to measure the price elasticity of secondary metal supply from old scrap (Bonczar and Tilton, 1975; Fisher, 1972) have found the elasticity to be greater in the short run than in the long run, which is just the opposite from what one normally finds with other sources of metal supply. However, as Figure 9c indicates, this unusual result should be expected only if the market price is above the price at which secondary supply from old scrap stocks is forthcoming, that is, above the price P_1 in Figure 9. When this is not the case, the figure suggests a change in price will produce a greater increase in supply in the long run than in the short run. Though as pointed out earlier, even here the phenomenon of accelerated scrapping can cause the response of supply to an increase in price to be greater in the short than the long run.

Nothing has been said so far about the immediate run and very long run supply curves for secondary metal from old scrap, in large part because the curves are not particularly unusual. The immediate run curve has the general shape illustrated for the competitive market in Figure 5. At very low prices, producers will save much or all of their current production, in hope of higher prices in the future. As price increases, however, and supply approaches the constraint imposed by current production, the supply curve turns upward and becomes quite inelastic.

The very long run supply curve has the general shape of the long run curve, and is similarly constrained by the metal content of the flow of old metal scrap. Indeed, in some circumstances, the two curves may coincide. Where high metal prices, however, stimulate old scrap recovery technology and thereby permit a greater proportion of the flow of old metal scrap to be economically recycled at any particular price, the very long run curve will lie somewhat to the right, and perhaps below, the long run curve.

Total Supply

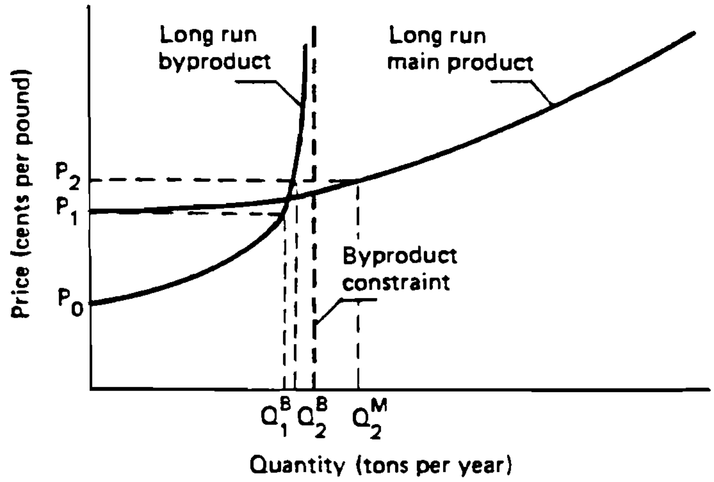
We have now examined the nature of supply for individual products, main products, coproducts, byproducts, secondary from new scrap, and secondary from old scrap. These various sources are all potential contributors to a metal's total supply.

To derive the total supply curve, we must add horizontally the individual curves for all significant sources (in a manner similar to that just used to derive the secondary supply curve for all old scrap from those for the flow of old scrap and for the stock of old scrap). For example, if the byproduct and main product supply curves for a metal are as shown in Figure 10a, and if other sources of supply are unimportant and can be ignored, the horizontal summation of these two curves gives the total supply curve shown in Figure 10b.

Among its many uses, the total supply curve provides an indication of the relative competitiveness of the different sources of supply, and in turn their relative importance at different market prices. For example, byproduct production is initially the most competitive and cheapest source of supply for the metal whose total supply curve is shown in Figure 10b. When market price is below P_1, it is the only source of supply. As the market price rises above P_1, however, main product production begins and becomes increasingly important. At the price P_2, main product supply exceeds byproduct supply.

A market price sufficiently high to call forth main product production permits most byproduct producers to realize a price considerably

a. Byproduct and Main Product Supply Curves



b. Total Supply Curve

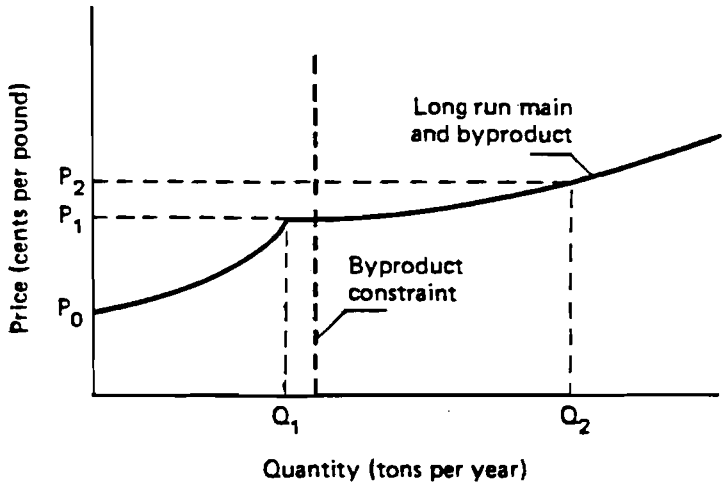


Figure 10. Total Long Run Supply Curve for a Metal Produced as a Byproduct and Main Product

above their reservation price, that is the price at which they are willing to sell their byproduct output and which normally reflects their production costs. This difference between costs and market price is economic rent. It accrues to all producers whose costs, including a normal rate of return on invested capital, are below the prevailing market price.

In deriving the total supply curve, a question sometimes arises as to whether the secondary supply curve for new scrap should be included. New scrap, after all, is generated in the manufacturing process, and depends on other sources of supply. If metal fabrication becomes more efficient and generates less new scrap, this does not mean total metal supply has declined.

Whether secondary supply from new scrap should be counted as part of total supply depends on the purpose for which total supply is being considered. In assessing the extent to which the United States is vulnerable to interruptions in supply from certain foreign producers, for example, we would not want to include secondary supply from new scrap. To do so, would ignore the fact that this metal is generated from other sources of supply, and so would not be available in their absence. Including secondary from new scrap in total supply would underestimate U.S. dependence on foreign producers. On the other hand, in assessing the competitiveness of secondary metal markets, we would normally want to consider secondary supply from new scrap.

Regardless of how secondary supply from new scrap is treated, it is important that total supply and demand be consistent in this regard. If the demand curve takes account only of metal actually contained or embodied in final products, and excludes metal that ends up as new scrap and is recycled, then total supply should also exclude new scrap. Conversely, if demand includes the demand for all metal, including that which ends up as new scrap, then the total supply curve should include new scrap as well.

APPLICATIONS

This section illustrates the usefulness of the supply and demand principles we have examined in the preceding sections. It uses these concepts to analyze metal market instability, the market impact of government stockpiling, and the "incentive price" technique for forecasting long run metal prices.

Market Instability[6]

Metal markets are well known for their instability, for their feast or famine nature. In an effort to stabilize commodity markets, particularly for the benefit of producers in the developing countries, the United Nations Conference on Trade and Development (UNCTAD) has over the last ten years pushed for the creation of an Integrated Program for Commodities. Among other measures, this program proposes to establish a common fund on which international commodity agreements can draw to support market stabilization measures. While the proposed program has encountered a number of difficulties, it does reflect the concern on the part of both producing and consuming countries over the instability that plagues mineral markets.

[6] This study draws upon Tilton and Vogely (1981) and Tilton (1977, Chapter 5).

Nor is this instability new. One of the major driving forces behind the multiple mergers in the American steel industry at the turn of the last century, which culminated in 1901 with the creation of the U.S. Steel Corporation possessing at that time some two-thirds of the country's steel making capacity, was a desire to control the volatile steel market (Temin, 1964). Gyrations in the steel industry during the 1880s and 1890s had created severe problems for all producers.

A highly concentrated market structure where one or a few major producers dominate the market and set a producer price does not, however, eliminate market instability (though as we shall see, it does alter the ways in which market instability manifests itself). This is because the following three characteristics of short run metal supply and demand, responsible for market instability, are present no matter how concentrated the market.

First, as output approaches the capacity constraint total supply becomes increasingly price inelastic. In a competitive market, as shown earlier, the short run supply curve turns upward and at some point becomes vertical. In a producer market, the curve simply ends, when major producers no longer have sufficient supply to satisfy demand at the producer price.

Second, demand also tends to be price inelastic. So the slope of the demand curve is quite steep.

Third, demand is highly elastic to changes in national income over the business cycle. The consumption of most metals is concentrated in four sectors--construction, capital equipment, transportation, and consumer durables--whose output is particularly sensitive to fluctuations in the business cycle. During a recession, these sectors suffer far more than the economy as a whole. During a boom, their sales soar. As a consequence, the demand curve for most metals shifts considerably over the business cycle.

These characteristics of short run supply and demand are illustrated in Figure 11a for a metal sold in a competitive market and in Figure 11b for a metal sold in a producer market. In both instances, it is assumed that supply comes from individual or main product production. This simplifies the analysis, but does not alter the conclusions, since total supply regardless of the combination of sources from which it is derived is at some output constrained in the short run by the available production capacity. As supply approaches this constraint, it becomes inelastic to price.

The two characteristics of metal demand--its inelasticity with respect to price and its elasticity with respect to income--are portrayed in Figures 11a and 11b by the steep slope of the demand curves and by the shifts in the demand curves over the business cycle. The curve DD_t reflects demand at the trough of the cycle, the curve DD_m at a mid point of the cycle, and the curve DD_p at the peak of the cycle.

One of the important consequences of market instability for copper, tungsten, and other metals sold on competitive markets is the severe fluctuation in market price. It varies in Figure 11a from a high of P_p at the peak of the business cycle to a low of P_t at the trough. The quantity of metal that producers supply to the market also varies greatly, from a

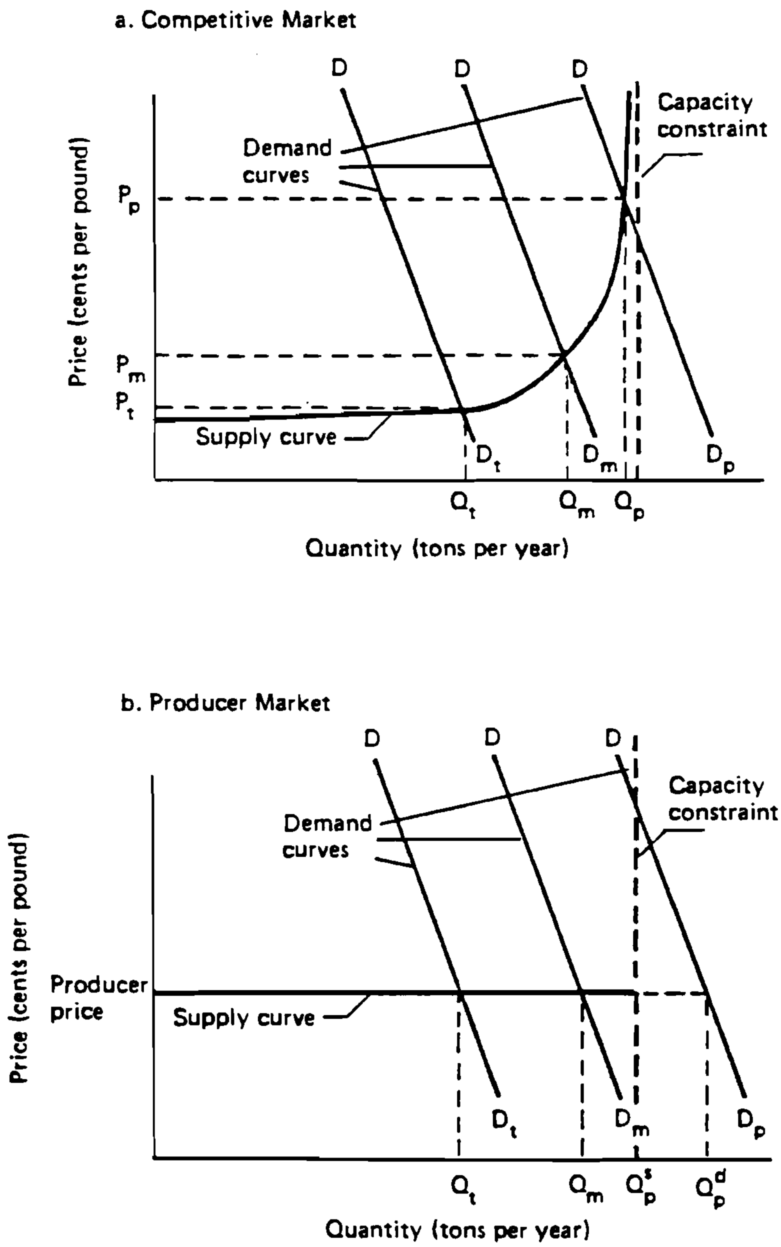


Figure 11. Short Run Supply and Demand Curves

high of Q_p (approximatey the maximum possible given the industry's production capacity) to a low of Q_t. At the latter level, producers are burdened with either shutting down much of their capacity or adding a large part of their output to their inventories.

Figure 11a also indicates that when market instability is caused by shifts in the demand curve (rather than by shifts in the supply curve, which is more typical for agricultural commodities), the quantity sold and price move together. When one is down, so is the other. Consequently, total revenues and in return profits tend to be highly volatile.

For metals sold in producer markets the situation is somewhat different. If all firms faithfully adhered to one producer price, there is no price instablity. Even if this is not the case, if some open or secret discounting occurs, or if the producer price is reduced when the market is weak, price instability will generally be less than in competitive markets.

However, physical shortages, where the available supply is insufficient to satisfy demand at the prevailing price, can occur in a producer market. In Figure 11b, for instance, the quantity demanded during the peak of the business cycle is Q_p^d while the maximum amount the industry can supply is only Q_p^s. The short fall requires that producers allocate or ration their limited supply to customers on the basis of past purchases or some other criterion.

Despite the greater price stability, firms in producer markets still suffer from sizeable fluctuations in total revenue and profits over the business cycle, as a result of the instability in metal demand and the impact that this has on sales. In these respects, the adverse effects of market instability are similar for producer and competitive markets.

Public Stockpiling

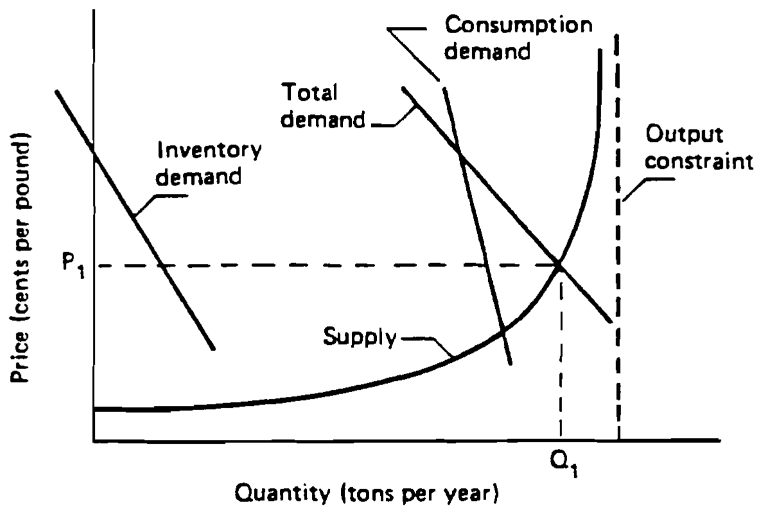
The U.S. government has for several decades maintained stockpiles of copper, lead, cobalt, tungsten, and a number of other metals for strategic purposes. More recently, France, Japan, and other industrialized countries have also contemplated such stockpiles, and in a few cases accumulated certain commodities.

This section examines how public stockpiling can affect metal markets. It begins by looking at the effects in the immediate run.

Earlier we distinguished between the immediate run supply curve in a producer market and in a competitive market. As shown in Figure 4, the curve for the producer market tends to be a horizontal line at the producer price that simply terminates once the constraint imposed by current output is reached. The curve for the competitive market, in contrast, starts at a lower price and rises gradually until the constraint imposed by current output is approached. It then turns upward and becomes vertical. These curves are reproduced in Figure 12.

In analyzing the effects of stockpiling, it is useful to separate total demand into three subcomponents or curves. The first is the consumption demand curve, which indicates the amount of metal demanded at various prices over the year for actual consumption. In Figures 12a and 12b this curve is shown with a relatively steep slope, since for reasons discussed earlier the demand for consumption tends to be quite

a. Competitive Market



b. Producer Market

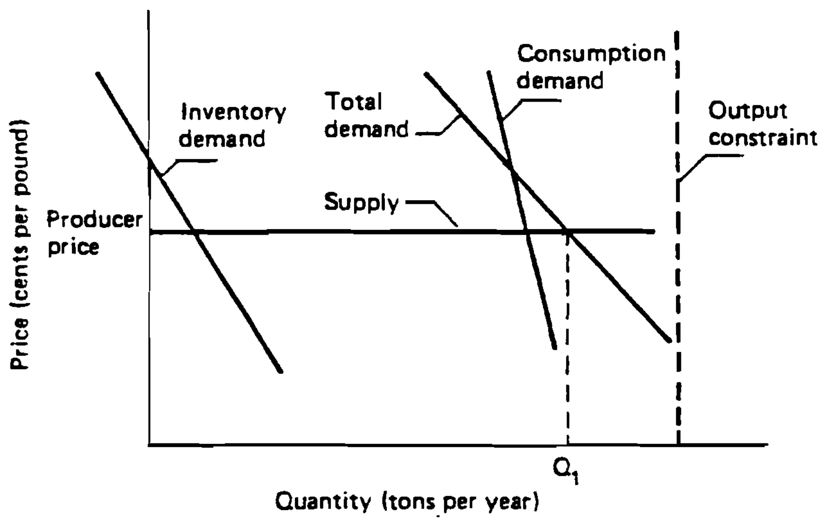


Figure 12. Immediate Run Supply and Demand Curves

unresponsive to price changes in the immediate run.

The second is the inventory demand curve, which shows the amount of metal demanded at various prices by fabricators, speculators, and others for inventory adjustments.[7] As the price of a mineral commodity rises, inventory demand is likely to fall, in part because carrying costs increase. In addition, the higher the current price, the greater and more widespread the expectation that price will fall in the future. For this reason, Figures 12a and 12b portray the inventory demand as moderately responsive to price. They also indicate that at high prices fabricators and others may on balance reduce their inventories, causing inventory demand to be negative.

The third is the stockpile demand curve, which shows the amount of the metal demanded by the government during the year in question for net additions to the public stockpile. The shape of this curve, which is not shown in Figures 12a and 12b, can be determined only with specific information about the purpose and operation of the public stockpile. It too can be negative, implying that the government wishes to dispose of some of its stockpile.

By adding these three individual demand curves horizontally, we can derive the total demand curve. If no public stockpile exists, only the demand curve for consumption and the demand curve for inventory need be added. Such a total demand curve is shown in Figures 12a and 12b.

[7]The inventory demand of producers is taken into account by the supply curve, as the amount producers supply to the market at various prices depends on their production and their demand for inventory. Consequently, it is not included in the inventory demand curve.

To assess the immediate effects of stockpiling, we need to know how the total demand curve, illustrated in Figures 12a and 12b, is altered when stockpiling occurs. This requires that we consider the nature and shape of the demand curve for net additions to the public stockpile in more detail.

Public stockpiles are created for a variety of reasons. As noted earlier, the United States maintains strategic stockpiles, which in principal are to be used only for military emergencies. The government has, however, on occasions used them to provide relief to distressed domestic mineral producers, to assist fabricators during shortages, and to discourage domestic producers from raising prices. It has also accumulated stocks to encourage the expansion of domestic mineral production. Other objectives are also possible. The International Tin Council, for example, operates a buffer stock to reduce the volatility of tin prices.

What is of particular importance in assessing the nature of the stockpiling demand curve is the rate of accumulation, not the current or desired size of the stockpile, and how this rate varies with the price of the metal. In this respect, a public stockpile will at any particular time be in one of three phases: the acquisition phase during which the government is purchasing the commodity and building up its stockpile; the disposal stage during which the government is selling the commodity and drawing down its stockpile; and the holding phase during which the government is neither buying nor selling the commodity but merely maintaining its stockpile at a given level.

If the rate of acquisition or disposal is fixed and does not depend on the price of the metal, the stockpile demand curve is simply a vertical line located to the right or left of the vertical axis shown in Figues 12a and 12b by the amount equal to the rate of acquisition or disposal. Under these conditions, and if government stockpiling alters none of the other demand or supply curves affecting the market (an assumption that is relaxed below), the immediate effects of public stockpiling can be readily appraised by recalculating the total demand curves shown in Figures 12a and 12b so that they include the demand for net additions to the public stockpile.

When the stockpile is in the acquisition phase, the total demand curve is shifted to the right by an amount equal to the rate of stockpile accumulation. For metals sold in competitive markets, this tends to increase the equilibrium price. Though the supply curve does not shift, the higher price will elicit an increase in supply. This increase, however, will not equal the rate of stockpile accumulation, since the higher price will reduce the demand for consumption and for additions to inventories. Figure 12a also indicates that the magnitude of these effects depends on market conditions at the time, and in particular where on the supply curve the industry is operating. When supply is substantially below capacity, acquisitions for a public stockpile have little effect on price, and hence on the demand for consumption and net additions to inventories. The major effect is simply an increase in supply and presumably production. In contrast, when the industry is operating at or near capacity, price increases significantly, and the demand for the public stockpile is largely accommodated by a reduction in the demand for consumption and additions to inventories.

For metals sold in producer markets, purchases for a public stockpile similarly shift the total demand curve rightward by an amount equal to the rate of acquisition. According to Figure 12b, this does not affect the price, nor the demand for consumption or inventory additions. The quantity supplied by producers simply expands to provide for the additional demand, assuming that existing capacity is sufficient to accommodate this increase. If this is not the case, government stockpiling produces a physical shortage. This presumably causes actual consumption and additions to inventories to fall below their demand at the producer price.

During the disposal phase, when the government is selling from the public stockpile, the immediate run effects are just the reverse of those for the acquisition phase. The total demand is shifted leftward by the rate of disposal. This tends to put downward pressure on price, to reduce production, and to stimulate demand for consumption and inventory additions. The relative magnitude of these effects, again, depends on how closely to full capacity the industry is already operating and on the manner in which prices are set. During the holding phase, when the government is neither buying nor selling for the stockpile, the total demand curve remains unchanged and the market is not disturbed.

So far our analysis rests on two rather restrictive assumptions: The first is that the rate of government acquisition or disposal for the public stockpile is invariant to the market price. The second is that the immediate run supply, inventory demand, and consumption demand curves shown in Figures 12a and 12b do not shift as a result of public stockpiling.

In practice, the rate of acquisition or disposal of public stockpiles is often influenced by market conditions including price. This is clearly the case for the buffer stockpile operated by the International Tin Council. It is also frequently true, as noted earlier, for the strategic stockpiles maintained by the U.S. government.

This means the stockpile demand curve is seldom a vertical line, but instead tends to slope downward. The lower the metal's price, the more likely stockpile accumulations will occur and the larger they are likely to be. Unfortunately, it is not possible to assess the nature of this relationsip in a general manner, for it varies greatly depending on the purpose of the stockpile, the metal in question, and numerous other considerations. Moreover, since stockpile demand depends on only one or a few public bodies it is much less likely that the relationship between this demand and price can be represented by a smooth continuous curve similar to that posited for the demand for consumption or for private inventory additions. This means that the stockpile demand curve must be assessed on a case-by-case basis, and even this may prove difficult.

In tin, for example, the U.S. government has in recent years indicated a willingness to dispose of excess stocks from the strategic stockpile. At no price, no matter how low, does the government appear willing at the present time to purchase tin. Nor does it appear willing to sell tin at depressed market prices, and for this reason has on occasions rejected all bids. In addition, for political reasons the government has recently reached an agreement with Malaysia, Thailand, and Indonesia that limits tin stockpile releases to 3000 tons per year. This suggests that the demand curve for net additions to the U.S. tin stockpile coincides with the vertical axis in Figues 12a and 12b until price reaches that level at which the government is willing to sell. At this point, the demand curve moves leftward following a horizontal path until the 3000 ton limit is reached, and there turns upward and again becomes a vertical line at higher prices.

Whether the preceding is a completely accurate picture of the immediate run demand curve for net additions to the U.S. tin stockpile can, of course, be debated. It does, though, illustrate the need for a case-by-case approach in assessing such curves. It also demonstrates one possible way in which stockpile demand may vary with price.

The second assumption holds that government stockpiling does not shift any of the supply and demand curves shown in Figures 12a and 12b other than the total demand curve. This seems reasonable for the consumption demand curve. In the immediate run, the demand for consumption is largely the result of the overall level of economic activity and consumer tastes, which determine the mix of final goods and services. Neither of these factors is likely to be affected by government stockpiling. The latter may alter the price of a mineral commodity, and thereby either encourage or discourage its consumption, but this reflects a movement along the consumption demand curve, not a shift in the curve.

The supply curve, it will be recalled, shows the amount producers will offer to the market at various prices. In competitive markets there is no reason to believe that government purchases or sales for stockpiling purposes affect the amount firms are willing to supply other than by altering the market price. So here, too, the assumption appears reasonable.

In producer markets, the entry of the government into the market to acquire stocks may prompt firms to raise the producer price, which would shift the immediate run supply curve upward by the amount of the price increase. Conversely, the disposal of government stocks could cause a drop in the producer price and the supply curve. So the list of possible effects of government stockpiling on commodities with producer prices should be expanded. Earlier this list included a change in the quantity supplied and the possibility of a physical shortage. With a shift in the supply curve, price also changes, which in turn affects the demand for consumption and inventory additions.[8]

Government stockpiling activity may also shift the inventory demand curve. During the acquisition phase, when the government is accumulating stocks, expectations of higher future prices and of physical shortages may encourage the private sector to build up its inventories. Such a rightward shift in the inventory demand curve augments the shift in total demand caused by public stockpile acquisitions, causing an accentuation in the immediate run effects of the latter. Similarly, the effects of stockpile disposals may be accentuated by a leftward shift in the inventory demand curve.

[8]Even without a shift in the supply curve, price and in turn the demand for consumption and inventory additions could change, if some firms discounted the producer price when demand was weakened, so that the supply curve was not completely horizontal as shown in Figure 12b.

The influence of government stockpiling on the inventory demand curve depends to some extent on the objective of the stockpile. For example, stockpiles designed to reduce short term market instablity or to augment available supplies in the event of import disruptions are likely to reduce the inventories held by the private sector. In this case, the shift in the inventory demand curve that accentuates the immediate effects of government stockpiling would be reduced and perhaps eliminated.

As a result of the influence of public stocks on inventory demand, a government with large stockpiles can affect conditions in mineral commodity markets without actually buying or selling. The announcement that the U.S. government planned to dispose of its excess tin stocks, for instance, had a dampening effect on that market, even though actual government sales for some time following this announcement were trivial. This occurred because the expectation of stockpile disposals shifted leftward the inventory demand curve, and in turn the total demand curve. Metal traders and others often maintain that the mere existence of a larger government stockpile may overhang the market and depress prices, presumably for this reason, even though the stockpile is in a holding phase. Such an overhang effect, however, is not likely unless the private sector anticipates a shift out of the holding phase and into either a disposal or acquisition phase in the near future. Nor is it likely to persist over an extended period unless the government does move out of the holding phase. Still, in the immediate run the overhang effect can have a substantial impact on metal markets.

During the acquisition stage, we have seen that public stockpiling tends to increase commodity prices and expand production. In producer markets, it may also promote physical shortages. These effects, which are realized immediately, influence investment behavior in two ways.

First, producers are more likely to build new capacity and less likely to shut down existing facilities. Over time this shifts the immediate run supply curve rightward. The extent of this shift depends on both the rate and duration of government accumulation. Little new capacity is likely to be added as a result of stockpiling that is over within a month or two. However, stockpiling that continues for several years may have an appreciable effect.

Second, metal consumers experiencing higher prices and possible shortages as a result of public stockpiling will look for alternative materials. If public stockpiling continues over an extended period, some fabicators are likely to turn to other materials, causing the consumption demand curve to shift rightward.

Thus, while the acquisition phase of public stockpiling initially stimulates the market--pushing prices up, expanding supply, and raising the possibility of physical shortages--if it persists for several years it produces shifts in the supply and consumption demand curves that tend to offset these effects. Conversely, during the disposal phase, the initial market impact is depressing. However, over time the induced shifts in the supply and consumption demand curves will moderate this impact.

If the government, after building up a stockpile for several years, decides that its size exceeds its requirements and shifts from an acquisition to a disposal phase, the depressing effect on the market will be accentated by the shifts in the supply and consumption demand curves induced by the earlier acquisition phase. In examining the market impact of U.S. strategic stockpiles, Gauntt (1980) identifies a number of such instances where the induced effects of earlier behavior reinforce the immediate effects and thereby compounded the market disruption of public stockpiling.

The preceding indicates that assessing the market consequences of public stockpiling is a complicated task. Even if the anticipated size of a stockpile is small, it can for a time have a significant impact depending on the speed with which the government acquires or disposes of stocks. Moreover, the direct effect of government purchases or sales may be accentuated, or moderated, by changes in the inventory behavior of the private sector induced by the current stockpiling activity and by the shifts in metal supply and demand resulting from earlier stockpiling efforts. In addition, both the magnitude and the nature of the consequences of public stockpiling may be influenced by the purpose or objectives of the stockpile, the manner in which it is operated, and the prevailing market conditions at the time purchases or sales are undertaken.

Forecasting Long Run Metal Prices

Firms studying the feasibility of developing new mines or for expanding existing facilities make forecasts of long run metal prices. Similarly, manufacturers contemplating the substitution of one material for another rely on price forecasts. Governments whose tax receipts and foreign exchange earnings follow trends in metal export markets, and local communities whose economy depends on mineral production, also have an interest in future price forecasts.

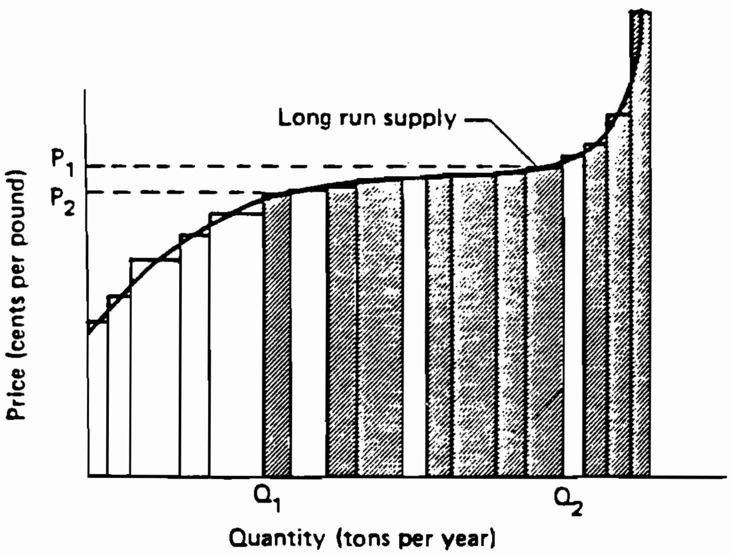
The "incentive price" technique is one method of making such forecasts. It assumes that over the long run a metal's price must approach that level which provides the necessary incentives to ensure production capacity just sufficient to satisfy demand.

As long as entry into the industry is not severly restricted, this condition is likely to be met. When market price is above the incentive price, new firms will enter the industry and existing firms will expand their capacity. The resulting increase in supply will eventually reduce price, and this downward trend will continue until the incentive price is reached and the expansion of existing capacity ceases.

Conversely, when the market price is below the incentive price, neither new firms nor established producers will be motivated to invest in new capacity. As existing facilities become obsolete and are retired from use, and as demand grows over time, the market price will rise. This upward movement will continue until the incentive price is reached and once again firms are willing to build new capacity.

Success in applying the incentive price technique lies in identifying the incentive price itself. While this can be extremely difficult, for some metals due to the nature of their long run supply it may be relatively simple.

Figure 13, for example, portrays the long run supply curve for a metal produced largely as an individual or main product, and sold in a competitive market. This curve is derived from the average total costs



Note: Shaded areas represent known but undeveloped deposits.

Figure 13. Long Run Supply Curve For a Metal With Many Undeveloped Deposits of Similar Quality

and annual production capacities associated with available deposits, both those actually in operation and those that are undeveloped but known to exist, along the lines discussed earlier. The undeveloped deposits, which are denoted by the shaded areas in Figure 13, are among the higher cost sources of supply, since lower cost deposits tend to be exploited first.

Because a very wide range of supply (from Q_1 to Q_2) is available in the long run over a narrow band of prices (from P_1 to P_2), the incentive price for the metal portrayed in Figure 13 may be relatively easy to determine. The long run supply curve has a relatively flat segment, such as that shown, when a number of large deposits of comparable quality and costs are known to exist and so are available for development. For example, many large porphyry deposits containing about 0.4 percent copper become attractive to develop at a copper price in the vicinity of 150 cents (in 1980 dollars) per pound.

If this flat segment of the long run supply curve is broad enough, it may cover all likely points of intersection with the long run demand curve. The incentive price can then be approximated from the estimated average production costs, including an adequate rate of return on invested capital, associated with those marginal deposits determining the relatively flat and wide portion of the long run supply curve.

Using this procedure, Radetzki (1983a) has estimated that the incentive price for aluminum is between 80 and 100 cents per pound, and that for copper between 120 and 150 cents per pound (both in 1980 dollars). At the time of his study, prices for both of these metals were substantially below these figures, allowing him to predict that aluminum and copper prices would rise over the long run.

The incentive price technique is a useful forecasting method, when the inventive price itself is easily and accurately determined. In the following circumstances, however, this is not the case.

First, when entry into the industry is restricted and one or a few firms set a producer price, the long run price may not approach the average production costs of the marginal deposits. In such situations, the determinants of long run price are more difficult to identify and assess.

Second, the long run supply curve may not have a broad flat segment. This depends on the quality differences among known deposits. If there is no tendency for a sizeable number of large deposits to share the same quality--the same ore grade, ease of access, and processing costs—there will be no narrow price band over which large quantities of supply are forthcoming in the long run.

Third, even if the long run supply curve possesses a broad flat segment, the range of possible intersection points with the long run demand curve may fall outside this segment. Some forecasters, for example, are now suggesting that large porphyry copper deposits may not be needed in the foreseeable future, in part because the growth in copper demand has slowed in recent years, and in part because more copper supply will be coming from secondary and coproduct production. As a consequence, the long run demand curve may intersect the long run supply curve before the latter flattens out in response to the availability of porphyry copper deposits of comparable quality.

Fourth, the discovery of new deposits and especially the development of new technology can cause the very long run supply curve to lie appreciably below the long run supply curve. Forecasting on the basis of the incentive price implied by the long run supply curve will as a result substantially overestimate the future price in some instances.

These considerations reflect violations of the four necessary conditions for obtaining reliable long run forecasts with the incentive price technique. It is important to consider whether these conditions are satisfied, before using the technique to predict future metal prices.

Market instability, government stockpiling, and long run price forecasting are only three examples of the usefulness of economic principles in analyzing metal markets. Many other possibilities exist. We could, for instance, have assessed the likelihood of a successful cartel in the world bauxite industry, the impact of another invasion of the Shaba province in Zaire on the cobalt market, the consequences for land based nickel producers of seabed mining, or the costs to domestic consumers of protecting the U.S. steel industry.

The three examples, however, suffice to demonstrate the usefulness of relatively simple economic principles of supply and demand for the analyst investigating metal markets and industries. The examples also indicate that these conceptual tools must be combined with specific knowledge about the nature of metal supply and demand. It is not enough to know that the demand curve in most markets is downward sloping. Some idea of just how responsive or unresponsive demand is to a price, and how this responsiveness varies from the immediate to the very long run, is essential. Some applications even require that the total demand be broken down into its various components, such as the demand for consumption, for inventories, and for government stockpiles.

Similar information is also needed on the nature of supply. To what extent, for example, does supply come from individual and main product output, from secondary production, from byproduct and coproduct production? How does market structure and the manner in which prices are determined affect supply? How responsive is supply to a change in price? How does this responsiveness change as supply approaches the constraint imposed by current production in the immediate run, by existing capacity in the short run, and by the availability of mineral deposits in the long run? How does the output or price of a main product affect the supply of its associated byproducts? How does secondary supply vary with metal consumption, prices, and the flow of old scrap?

No single set of answers to such questions is valid for all metals. The answers may even change for the same metal, as technology and other conditions evolve over time. So the good analyst of metal markets must know his economic principles, but he must also know how technology, institutions, market structure, and government policies shape metal supply and demand.

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