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**The Influence of Exchange Rate Movements
on World Copper Supply**

by

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by William B.P. Robson

A thesis submitted to the Faculty of
Graduate Studies and Research in partial
fulfilment of the requirements for the degree of
Master of Arts
in International Affairs

The Norman Paterson School of International Affairs
Carleton University
Ottawa, Ontario
Canada

28 January 1987

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ISBN 0-315-35827-0

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Graduate Studies and Research acceptance of this thesis, submitted
by William Robson, in partial fulfilment of the requirements for the
degree of Master of Arts.

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Abstract

Following recent studies using "real effective" exchange rate indexes -- trade-weighted measures adjusted for inflation -- to examine the influence of exchange rate fluctuations on the competitive positions of national goods-producing industries, this paper adopts the world copper mining industry as a case study. It examines the importance of exchange rate movements to commodity producers, and develops a set of such indexes for the major copper-producing countries. Casual observation and statistical tests indicate that movements of producers' real effective exchange rates against each other from 1961-85 are correlated with changes in market share. A long-term declining trend of producer exchange rates relative to those of consumers is also discovered. The paper offers several observations on the possible causes and consequences of these phenomena, including implications for producer strategy and copper market stability.

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1 Introduction

1.1 Purpose

In recent years, the influence of exchange rates on commodity markets has attracted increasing attention. This paper focusses on the impact of exchange rate movements on the supply side of the world copper market, and develops a new measure designed to capture the effects of these movements on the competitive positions of the copper industries in the principal copper producing countries.

Chapter 2 provides an introduction to the salient features of the copper market. A brief outline of the uses of copper is provided in the section on demand; the section on supply gives detailed profiles of the major producers. The section on price describes the conditions under which copper is traded, and shows the course of prices in consuming country currencies since 1961.

Chapter 3 outlines the importance of exchange rate movements to the copper mining industry in a single country. The effect of exchange rate changes on the competitive situation of a national industry vis-a-vis its competition in other countries is then illustrated.

The exchange rate and inflationary experience of the major copper suppliers since 1961, and their resulting real

effective exchange rate indexes against other producers, are set out in Chapter 4. (The theory behind the formulation of specialized exchange rate measures in general, and the development of the real effective exchange rate indexes used in this paper is described in the appendix.)

Chapter 5 introduces a single equation test for correlation between movements of producers' exchange rates against each other and changes in their respective market shares, and presents the results of this test, based on annual data from 1961 to 1985. A more detailed analysis of the 1980-85 period, and the principal conclusions of the paper, are presented in Chapter 6.

1.2 Background

The events of the last two decades have focussed substantial attention on the means by which exchange rate movements affect commodity markets. Most important were the advent in the early 1970s both of a general system of floating exchange rates and of a period of considerably greater volatility in commodity markets. The phenomenal appreciation of the US dollar from mid-1980 to early 1985 produced pronounced divergences in prices measured in US dollars -- and in currencies tied closely to the US dollar -- and prices measured in other units. These events demonstrated in dramatic fashion that the behaviour of commodity prices is very much a function of the behaviour of the currencies in which they are measured.

In part, this development is simply inconvenient for commodity market analysts -- it is often difficult to state simply and unambiguously whether the price of an item has risen, declined, or remained constant in a given period -- but it has also had more tangible effects. The operation of international commodity agreements, for example, has been complicated considerably by changes in the exchange rate of the currency in which prices are monitored. The recent histories of the International Coffee, Rubber and Tin Agreements might have been quite different if curren-

cies other than those actually chosen had been used to track prices.¹

For commodity producers themselves, the divergences of price in different countries that exchange rates have caused are matters of considerably more than passing interest. In many primary industries, even small variations in price can mean the difference between profitable operation and bankruptcy. Many of those engaged in basic industries in North America during the past five years have noted the differentials between the higher prices being received by their competitors -- particularly in LDCs -- and the low prices they themselves receive, and have blamed exchange rate changes for their difficult financial circumstances.²

1 This has led to proposals for the use of the SDR, or individual "commodity units of account", in these agreements. See OECD, Exchange Rates and Commodity Markets CE/CG(85)21 (Paris: 1985) pp. 13-15; and OECD, Use of Currency Baskets in International Commodity Agreements CE/CG(86)3 (Paris: 1986).

2 This theme was particularly prominent in the 1984 financial statements of North American mineral producers. Phelps Dodge cited the high US dollar as a factor in the closure of several of its operations (Phelps Dodge Corp., Annual Report, 1984). Canada's Teck Corp. detailed price changes of copper and gold since 1980 in various currencies in support of an argument in favour of a devaluation of the Canadian dollar (Teck Corp., Annual Report, 1984 pp. 14-15).

1.3 The Study of Exchange Rates

The literature on exchange rates and the determinants of their behaviour is voluminous. The modern investigation of the subject might be said to date back to the development of the theory of purchasing power parity by the Swedish economist Gustav Cassel in the early decades of this century.³ The intervening years have seen the study of exchange rates spurred on by a virtually continuous broadening and deepening of foreign exchange markets resulting from faster communications and new financial instruments. As the quantity and quality of data relevant to the investigation of exchange rates have been augmented (and opportunities for its profitable use have multiplied), the theory of exchange rate behaviour and its quantitative analysis have become increasingly sophisticated.

The advent of the general floating exchange rate system has encouraged greater investigation of the impact of exchange rates on specific areas of economic activity. Discussion of the impact of exchange rate movements on the relative profitability of various pursuits within a country is standard in texts on international economics. Similarly, virtually all authors on economic development make at

3

Gustav Cassel, The World's Monetary Problems (New York: 1921) and Money and Foreign Exchange after 1914 (New York: 1922). The theory of purchasing power parity is explained in the notes to Section A.3, "Real Measures", in the appendix.

least token mention of the importance of appropriate exchange rate management in development.⁴ Of particular interest, in the context of this paper, has been the development of exchange rate measures that facilitate the analysis of the effects of currency movements on the balance of payments of an individual country, or trade in a particular good.

⁴ See, for example, Michael Todaro, Economic Development in the Third World (New York: 1981) pp. 381-86, and C.P. Kindleberger and B. Herrick Economic Development (New York: 1983) pp. 432-38. A more detailed account of the importance of proper exchange rate management for mineral-exporting LDCs can be found in Gobind Nankani, Development Problems of Mineral Exporting Countries, World Bank Staff Working Paper No. 354 (Washington: 1979).

1.4 The Study of Commodity Markets

Commodity market analysis is, likewise, not a new subject. The study of the production, consumption, trade and pricing of raw materials is as old as the discipline of economics. Commodity markets have been the target of a great deal of research, not only because of their importance, but also because their study is comparatively easy, due to the homogeneity of the product and the relative transparency of most commodity markets.

Recent years have seen an increase in the application of quantitative and mathematical techniques to commodity market analysis, and pronounced growth in the use of formal mathematical models.⁵ As has been the case with the study of exchange rates, academic (and profit-seeking) students of the subject are the beneficiaries of the steady development of competitive and highly liquid markets for various materials.

⁵ For a review of recent work, see W.C. Labys and P.K. Pollak, Commodity Models for Forecasting and Analysis (New York: 1984).

1.5 The Influence of Exchange Rates on Commodity Markets

Study of the ways in which exchange rates affect commodity markets is, on the other hand, a comparatively new area. It is still too early to speak of a body of analysis on the subject. Much discussion of exchange rate effects in particular markets has been of an ad hoc descriptive nature. Different oil consumption trends in the major industrial countries, for example, have frequently been explained in part with reference to exchange rate movements; while with regard to copper, Chilean production in the 1980s has been cited as an example of exchange rate-induced changes in quantities traded.⁶

Not surprisingly, the International Monetary Fund (IMF) and the World Bank have been in the forefront of more systematic work in this area. The importance of exchange rate developments in commodity trade has received considerable attention in the past several issues of the IMF's World Economic Outlook and the World Bank's World

6

IMF, World Economic Outlook 1985 (Washington: 1985) pp. 144-45; and OECD, Exchange Rates and Commodity Markets, p. 13.

Development Report.⁷ Generally, however, there has not been much systematic application of exchange rate fluctuations to explain commodity market developments, and very little use of exchange rate-related variables in commodity market modelling.⁸

7 For a simplified algebraic treatment of the problem, see James M. Broughton et al., "Effects of Exchange Rate Changes in Industrial Countries: Appendix I, Effects of Exchange Rate Changes on Prices of Internationally Traded Commodities," IMF, Staff Studies for the World Economic Outlook (Washington: 1986) pp. 145-46. The IMF's 1983 World Economic Outlook presented the results of a statistical analysis of the behaviour of commodity prices with reference to a variety of factors, including the value of the US dollar, but expressed doubts about their reliability (IMF, World Economic Outlook 1983 [Washington: 1983] p. 158). Subsequent work suggested an elasticity of dollar prices with respect to exchange rate changes in the dollar against other major currencies of -0.75 with no lag (IMF, World Economic Outlook 1985 [Washington: 1985] pp. 135-38). The 1985 World Development Report deals with the effect of the strong US dollar on commodity prices, stating that "empirical analysis shows that a 10% real appreciation of the US dollar brings real commodity prices in terms of US goods down by 6%" (World Bank, World Development Report 1985 [New York: 1985] p. 32).

Of particular note is a recent study by Christopher Gilbert of the World Bank. He concludes that, during the first half of the 1980s, a 10% appreciation of the US dollar has tended to be associated with a 9% fall in commodity prices (11% in the case of metals and minerals), of which 6% is a direct response (7% for metals and minerals). The remainder is a combined consequence of greater than proportional devaluations of the currencies of LDC exporters and increased production from these countries necessitated by an increase in dollar-denominated debt. See Christopher Gilbert, The Impact of Exchange Rates and Developing Country Debt on Commodity Prices, World Bank Commodity Studies and Projections Division Working Paper (March 1986).

8 Labys and Pollak, pp. 156 and 160-61, comment on this absence. There are, however, instances of the investigation and use of such variables, several of which are worthy of note:

1. The desirability of transforming international (US dollar) price series into domestic currencies prior to estimating national supply and demand equations was the subject of H.F. Bjarnson et

al., "Converting Price Series of International Commodities to a Common Currency Prior to Estimating National Supply and Demand Equations," American Journal of Agricultural Economics 51:1 (February 1969).

2 Considerably more sophisticated is Alan Gelb's "A Spectral Analysis of Coffee Market Oscillations," International Economic Review 20:2 (June 1974). His analysis of coffee price cycles and the production decisions of producers led him to conclude that a fundamental cause of price instability was "the separation of producers and consumers into differing currency areas with coffee accounting for a substantial portion of inter-area trade" (p. 512).

3 More recently, Dallas Batten and Michael Belongia have studied the effects of the strength of the US dollar on American agricultural exports. Using a one-equation model of US agricultural exports containing a real effective exchange rate index of the US dollar against foreign currencies, they conclude that the strong dollar has had a significant negative influence on these exports. See Dallas S. Batten and Michael T. Belongia, "The Recent Decline in Agricultural Exports: Is the Exchange Rate the Culprit?" in the Federal Reserve Bank of St. Louis Review (October 1984).

4 A similar study was undertaken by Jeffrey Rosenweig: "The Dollar and the US Travel Deficit," in the Federal Reserve Bank of Atlanta Economic Review (October 1985). Experiments with a one-equation model led him to conclude that the rise in the dollar had played a significant part in the widening of the US travel deficit since 1980.

5 Also of considerable interest in the context of this study are the metals market models of Resource Strategies Inc. (RSI). These are described in detail in Chapter 5.

1.6 Copper as a Commodity for Study

For the type of investigation undertaken in this paper, copper has several virtues. To begin with, it has been extensively studied. Relevant data on it are collected by a number of agencies, and are generally of high quality. A large number of studies on copper and several econometric models of the copper market exist, providing a wealth of information about the history of the market and the behaviour of its participants.

Further, copper is a relatively homogeneous commodity, traded in a well integrated market. Tariffs are generally low, and free market prices form the basis for most transactions. In addition, value added in the mining stage accounts for the bulk of the price of refined copper.⁹

9

UNCTAD, Processing and Marketing of Copper: Areas for International Cooperation (Geneva: 1982) gives the following table (p. 44) of relative prices of various copper products (with fire refined copper serving as the base and set at 100):

Copper Price Relatives

Copper in Concentrate	75
Blister	90 - 95
Fire Refined	100
Continuous-Cast Grade Cathode	103
Wirebar	105
Wire Rod	110
Wire (bare)	130 - 140
1 mm Sheet	180 - 200

Consequently, it is easy to identify the stage of production at which the effects of exchange rates on competitiveness are most likely to be felt.¹⁰

Finally, the fact that the production and consumption of copper occur largely in different geographic areas, under different exchange rate regimes, makes it one of the more interesting commodities for a study of this type.

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It should be mentioned, however, that because of the small value added in processing from the concentrate stage, even low tariffs on smelted and refined products may afford significant effective protection to these activities. Processing facilities established as a result of protective measures, or obtaining them, may affect production decisions in the primary stage through ties of ownership or the actions of governments.

2 The Copper Market

A review of the western world copper market¹¹ -- involving a description of the major copper using industries and countries, along with profiles of the major copper producing countries -- is necessary to an understanding of the market balance and price trends of the 1961-85 period, and the role played by exchange rate changes in this history.¹²

¹¹ In this paper, "western world" is used to mean the market economy countries, or the non-communist world plus Yugoslavia. It has been chosen in place of more precise labels because it is economical and is readily understood.

¹² A number of good surveys of the copper industry are available, though many are becoming dated. Orris Herfindahl's Copper Costs and Prices (Baltimore 1959) remains a classic. Two other informative and readable surveys are Sir Ronald Prain, Copper: The Anatomy of an Industry (London: 1975), and R.F. Mikesell, The World Copper Industry: Structure and Economic Analysis (Baltimore: 1979). Extensive factual and statistical coverage of the industry is provided by the US Bureau of Mines (USBM), the World Bureau of Metal Statistics (WBMS), the Copper Development Association, and numerous trade and technical magazines. The following discussion is based principally on these sources. In addition, high quality analysis of the industry is available from proprietary sources such as the Commodities Research Unit (CRU), Resource Strategies Inc. (RSI) and Brook Hunt and Associates.

2.1 Demand

Copper is the world's third most important industrial metal, after iron and aluminum. It is generally regarded as having been the first metal used by man for other than ornamental purposes. Copper has been valued for millennia because of its strength, malleability, and resistance to corrosion, complemented by its beautiful appearance. In more recent times, its excellent electrical and thermal conductivity -- in which properties it is second only to silver -- have led to a wide variety of industrial applications. Consumption of copper by major industrial sector is set out in Table 2.1.1.

Table 2.1.1 Share of Major Industries
in Western World Copper Consumption

Building construction	30%
Electrical	27%
Industrial equipment	20%
General and consumer goods	12%
Transport	11%

Source: Department of Energy, Mines and Resources (Canada).

The bulk of consumption in the construction, electrical, and consumer goods industries consists of wire, used either to conduct power or data, or as electrical windings in motors and generators. The use of wire in all sectors accounts for roughly half of all copper consumption. Most of the remainder is consumed in the form of brass mill

products, either as pipe, or as heat exchangers in automotive radiators, refrigerators and air conditioners. Other less important uses of copper are in coinage, ammunition, roofing, and chemical compounds.

Given this consumption profile, it is not surprising that Europe, North America and Japan account for by far the greatest part of western world demand for copper. As Table 2.1.2 indicates, use in these areas represented almost 85% of 1985 consumption. Despite spectacular growth in some LDCs -- South Korea's consumption in 1985 was over seven times that of a decade earlier -- the overall importance of the less developed world in copper demand remains small.

Table 2.1.2 1985 Western World Consumption
 of Refined Copper, by Region

	'000 tonnes	Percent
United States	1,917.8	26.5%
Canada	222.5	3.1%
Other Americas	414.8	5.7%
France	390.7	5.4%
Germany	755.0	10.4%
Italy	359.0	5.0%
United Kingdom	346.5	4.8%
Other Europe	878.0	12.1%
Africa	89.0	1.2%
Japan	1,230.8	17.0%
Other Asia	500.4	6.9%
Oceania	124.6	1.7%
Total	7,229.1	100.0%

Source: World Bureau of Metal Statistics (WBMS).

The course of western world consumption since 1961 is illustrated in Figure 2.1.1.¹³ The extent to which copper consumption is influenced by economic cycles is clear from this graph. Relatively rapid and steady growth over the 1961-73 period has been followed by a slower and more erratic pattern, with sharp dips in consumption occurring in 1975 and during the 1982 recession.

Figure 2.1.1

Refined Copper Consumption

Western World Plus Net CPE Imports

(thousands of tonnes)

Source: MBMS, World Metal Statistics.

13

For convenience of illustration, consumption includes net exports to the centrally planned economies (CPEs). The CPEs, as a group, were net importers of copper up to 1971 and, with the exception of 1974, net exporters up until 1983. In 1983 and 1984, large Chinese imports resulted in another reversal. With the exception of these two years, east-west trade in copper has been quite small relative to the total size of the market.

2.2 Supply

The bulk of copper consumed each year is produced from mines.¹⁴ Mined ore is first crushed, and then separated from the tailings by floatation. The resulting concentrate, generally containing about 30% copper, is dried, sometimes roasted, and fed into a furnace for smelting. In the furnace, impurities are burned away, leaving a liquid copper matte, which is cast into anodes. These anodes are then placed in electrolytic tanks for refining. The resulting refined cathodes are either cast into commercial shapes, such as wirebars, ingots or billets, or continuous-cast into large coils of rod, suitable for working into wire.

The most important of the world's exploitable copper reserves, mined in the Americas and in central Eurasia, are porphyry deposits -- large, low-grade sulphide ores. These deposits usually present relatively few mining and metallurgical problems, and often contain molybdenum, gold and silver. Metamorphosed porphyries, or skarn deposits, are of importance in southeast Asian producers. These

¹⁴

About 16% of the western world's refined copper is produced from scrap recovered from industrial processes and obsolete items.

deposits are typically very low grade, but tend to have higher gold values than the porphyries.

Sedimentary deposits represent a second major source of copper. The most significant of these are found in the copperbelt of Zambia and Zaire. These deposits are typically high grade -- from 2% to 5% copper -- but their complex stratabound structure presents problems in mining and concentrating. The deposits in the copperbelt also yield cobalt as a byproduct.

A third major source of copper is polymetallic massive sulphide deposits. The most important of these are in Canada: in the Canadian shield regions of Manitoba and Ontario, copper is generally associated with zinc; in the Sudbury region, it is a byproduct of nickel mining; and in northern Quebec, copper is a co-product with gold. Similar deposits are found in various areas of Europe, Japan, the United States and Australia. Finally, small quantities of copper are produced as a byproduct of silver and lead lodes in the United States, Mexico and Peru.

The distribution of world copper reserves by region is shown in Table 2.2.1. The reserve base represents measured and indicated copper resources, while reserves constitute that proportion of the resource that can be mined economically (about 70% of the reserve base). Of the world total,

85% and 90% of the reserves and the reserve base respectively are located in the western world.

Table 2.2.1 World Copper Reserves by Region
(millions of short tons)

	Reserves	Reserve Base
Canada	15	32
United States	57	90
Mexico	17	23
Chile	79	97
Peru	12	32
Other Americas	4	27
Europe	50	70
Zaire	26	30
Zambia	30	34
Other Africa	4	7
Philippines	12	18
Other Asia	24	19
Australia	8	16
Oceania	7	18
World total	350	510

Note: Totals are rounded.

Source: USBM, 1983 Yearbook.

Copper has been exploited in several parts of the world for thousands of years. However, most of the deposits of greatest significance in modern copper supply became available only with the development of modern large-scale open pit, bulk mining techniques in the late nineteenth and early twentieth centuries. The years from 1880 to World War One saw the development of the porphyries in the western United States. The opening of the first large scale mines in Chile and the African copperbelt dates from the 1920s.

In the years following the Second World War, the steady and speedy growth of industrial demand, as well as the diffusion of technical knowledge and engineering ability, played a part in the development of numerous new mines in the Americas, parts of Asia and Africa, and Australia. In 1985, western world mine production of copper was as shown in Table 2.2.2.

Table 2.2.2 1985 Western World Production
of Mined Copper (by Region)

	'000 tonnes	Percent
United States	1,092.1	16.9%
Canada	724.4	11.2%
Mexico	180.0	2.8%
Chile	1,356.4	21.0%
Peru	390.5	6.0%
Other Americas	37.8	0.6%
Europe	334.9	5.2%
Zaire	512.7	7.9%
Zambia	519.6	8.0%
RSA and Namibia	250.0	3.9%
Other Africa	58.9	0.9%
Philippines	226.2	3.5%
Other Asia	340.7	5.3%
Australia	266.0	4.1%
Papua New Guinea	175.0	2.7%
Total	6,465.2	100.0%

Source: WBMS.

Although copper mined as a byproduct of other metals constitutes a relatively small proportion of total western world output, it is an important component of production in

several areas.¹⁵ The following table shows, by region, the significance of byproduct mine capacity -- measured in thousands of metric tonnes per year (tpy) -- in the western world.

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Table 2.2.3 1983 Western World Copper Mine Capacity by Product Type

	Principal Product		Byproduct		Total
	'000 tpy	%	'000 tpy	%	'000 tpy
United States	1,545	99.4%	10	0.6%	1,555
Canada	724	81.1%	169	18.9%	893
Chile	1,392	100.0%	0	0.0%	1,392
Peru	376	91.9%	33	8.1%	409
Mexico	230	85.2%	40	14.8%	270
Other Americas	50	96.2%	2	3.8%	52
Europe	368	88.0%	50	12.0%	418
Zaire	613	100.0%	0	0.0%	613
Zambia	609	100.0%	0	0.0%	609
RSA & Namibia	250	88.7%	32	11.3%	282
Other Africa	51	64.6%	28	35.4%	79
Philippines	370	100.0%	0	0.0%	370
Other Asia	606	98.4%	10	1.6%	616
Australia	222	91.0%	22	9.0%	244
Western World	7,406	94.9%	396	5.1%	7,802

Source: Department of Energy, Mines and Resources (Canada).

Western world production of refined copper, from both scrap and mined ore, over the 1961-85 period is shown in Figure 2.2.1. The following subsections describe the principal copper producing countries in greater detail.

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In this discussion, byproduct copper means copper contributing under 30% of a mine's 1983 revenue.

Figure 2.2:1

Refined Copper Production

Western World

(thousands of tonnes)

Source: MBMS, World Metal Statistics.

2.2.1 The United States

Until it was surpassed by Chile in 1982, the United States was the world's largest copper producer.¹⁶ From 1961 to 1985, copper from US mines amounted to almost one quarter of the western world total. Virtually all of US production is from large, low grade, open-pit operations in the southwest -- predominantly Arizona, with smaller amounts coming from New Mexico, Utah, Montana and other states. Less than 1% of US mine output is as a byproduct of the production of other minerals.

US mine production is shown in Figure 2.2.1a, while Figure 2.2.1b shows US output as a proportion of the western world total. Output peaked at 1.56 million tonnes in 1970. Although this figure was almost reached in 1973 and again in 1981, the overall trend in production over the last decade has been downward. From 1983 to 1985, the US

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Except where noted, the information in these subsections is drawn from the USBM Yearbook (commodity and international area surveys), 1961 to 1984. The production data in the graphs are from the World Bureau of Metal Statistics, World Metal Statistics (various editions) and show the recoverable copper content of ores and concentrates produced. Figures on output lost to strikes, natural disasters, and other disruptions are my own estimates, based on data from these sources, as well as Metals Week, Metal Bulletin, Mining Journal, Department of Energy, Mines and Resources (Canada), Canadian Minerals Yearbook, and USBM, Minerals and Materials: A Bimonthly Survey.

Figure 2.2.1a

Source: WBMS, World Metal Statistics.

Figure 2.2.1b

mined between 1.0 and 1.1 million tonnes of copper annually, and its market share had fallen from over 30% in 1970 to around 17%.

US output over the 1961-85 period has been punctuated by a number of significant strikes on a three-year cycle, reflecting the expiry of industry-wide contracts. The most severe disruption was from July 1967 to the spring of 1968. At its peak around the beginning of 1968, the strike had idled about 90% of the industry. Close to 500 thousand tonnes of production were lost in 1967 as a result, with the 1968 figure about half that. A strike of similar magnitude, although shorter, occurred in the summer of 1980, curtailing production by almost 400 thousand tonnes. Smaller, though significant, disruptions occurred in 1964, 1971, 1974 and 1977.

2.2.2 Canada

Over the 1961-85 period, Canada accounted for just under 12% of western world production. Since the early 1970s, it has been the western world's third most important supplier of mined copper. Canada is unique among major suppliers in the proportion of its output -- about one fifth -- produced as a coproduct with, or a byproduct of, other metals. The country's largest copper producer, Inco, derives the bulk of its revenue from nickel, while the most important product of the second largest producer, Kidd Creek Mines, is zinc. As the price of copper has fallen, many producers in the important mining region of northern Quebec have been able to continue production because of rich gold values. As a consequence, Canadian copper production is to a considerable extent a function of developments in the markets for these metals.

Interrupted by a lengthy strike at Inco in 1969, Canadian copper production grew strongly (see Figure 2.2.2a) during the 1960s and early 1970s, to reach a peak of 824 thousand tonnes in 1973. Market share, shown in Figure 2.2.2b, peaked at 13.7% in 1967, having been boosted by the US strike. Like that of the US, the overall trend of Canadian production during the more difficult years since 1973 has been downward. Strikes had an impact on

Figure 2.2.2a

Source: WBMS, World Metal Statistics.

Figure 2.2.2b

Canada's output in every year during the 1970s, with the most significant cuts occurring during another prolonged strike at Inco in 1978-79. In 1982, Canadian market share fell below 10% for the first time during the period; in 1984 and 1985, it returned to a level slightly over 11%.

2.2.3 Chile

From 1961 to 1985, Chile supplied almost 16% of the western world's mined copper. Now the largest producer in the world, Chile has often been called the Saudi Arabia of copper. Its reserves -- amounting to over one fifth of the world total -- are relatively high grade and easy to exploit, and are sufficient to sustain present production levels for over a century. All of Chile's copper is produced as a principal product.

The steady growth of Chilean output since 1961 is evident from Figure 2.2.3a. During the 1960s, growth of output was constrained by frequent labour unrest, and a conservative stance on the part of the American mining companies controlling the industry at the time.¹⁷ After touching a low of 12.2% in 1973 (Figure 2.2.3b), however, Chile's market share has risen markedly, as major expan-

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The charge that Anaconda and Kennecott were not investing sufficiently in Chilean production was frequently levelled at the time. (See T.H. Moran, Multinational Corporations and the Politics of Dependence: Copper in Chile [Princeton: 1974].) Given the importance of these companies in the market, and their sensitivity to the charge of investing overseas at the expense of their US properties, the reluctance of Anaconda and Kennecott to boost Chilean output is understandable. This motivation, given the vigorous expansion of the Chilean industry after nationalization, makes the charge credible.

Figure 2.2.3a

Source: MBMS, World Metal Statistics.

Figure 2.2.3b

sions have been undertaken, particularly at the mammoth Chuquibambilla and El Teniente mines of state-owned Codelco, by far the dominant force in the Chilean industry. During the 1980s, strikes and other disturbances have again become significant. By 1985, however, Chilean production had surpassed 1.3 million tonnes, and Chile was supplying over one fifth of the western world's mined copper.

The Chilean economy is markedly dependent on copper. Over the 1961-85 period, about 65% of Chile's foreign exchange earnings came from copper exports. This dependence was most pronounced during the years 1965-69, when the proportion of earnings from copper averaged over 80%. Since the late 1970s, copper's share of export revenue has fallen below half (to 46% in 1985), as a consequence of diversification of the Chilean economy and weaker copper prices. The mining industry in Chile, which is overwhelmingly dominated by copper, has in recent years accounted for about 10% of GDP and 15% of government revenue.

2.2.4 Peru

Peru is the least significant of the copper suppliers profiled individually in this section, having accounted for about 5% of total western world mine output since 1961. Multi-metal mines make up a significant proportion of the Peruvian industry, and byproduct production accounts for about 9% of Peru's output.

Peruvian production of copper is shown in absolute terms and as a proportion of the western world total in Figures 2.2.4a and 2.2.4b respectively. Peru's importance in the copper market was enormously enhanced during the latter half of the 1970s by the development of Southern Peru Copper Corporation's (SPCC's) Cuajone pit, which opened in 1976, and to a lesser extent by the start-up of the Cerro Verde project in 1977. Strikes are endemic in the Peruvian mining industry, and labour unrest has affected output in virtually every year.

Over this period, Peru derived approximately 20% of its export revenues from copper. Like Chile, Peru's dependence on copper was greatest during the late 1960s, when copper's share of export revenue was between 25% and 30%. In recent years, it has fallen to around 15%.

Peru

Production of Mined Copper

(thousands of tonnes)

Source: MBMS, World Metal Statistics.

Figure 2.2.4b

Peru

Market Share

(Western World Production of Mined Copper)

2.2.5 Zaire

Zaire has produced about 7.5% of the western world's copper from 1961 to the present. None of Zaire's copper is mined as byproduct. The growth of Zairean output during the decade to 1973 (Figure 2.2.5a) and its relative flatness since that year, mirror the overall trends of the copper market fairly well. As a consequence, Zaire's market share (Figure 2.2.5b) has remained remarkably steady.

Erosions in Zaire's contribution to world supplies occurred in the early 1960s as a result of political turmoil, and again in the mid- and late 1970s, with the Angolan civil war (which closed the Benguela railway, essential for supplies and deliveries) and the subsequent invasion, from Angola, of Zaire's copper producing regions in 1978. In recent years, Zaire has been remarkable for maintaining output despite virtually chronic shortages of fuel, supplies and skilled workers -- 1985's production, at 513 thousand tonnes, was a new high.

Zaire was the first of the LDC copper producers to expropriate the foreign multinationals operating in the country, with the takeover of Belgium's Union Miniere du Haut Katanga in 1967. In 1972, a joint venture between the

Figure 2.2.5a

Source: MBMS, World Metal Statistics.

Figure 2.2.5b

government and a Japanese consortium was established, but never made a profit. The Japanese investors abandoned it in 1983, leaving the state-owned Gecamines the sole force in the Zairean industry.

Over the 1961-84 period, copper accounted for a little over half of Zaire's export earnings. Zaire's dependence on copper exports peaked in 1969-70, when copper earned two thirds of export revenue. More recently, its share has been around 45%, although in 1982 -- as prices of other exports fell -- it reached 58%. Even in that depressed year, the Zairean government obtained 15% of its revenues from taxes on Gecamines.

2.2.6 Zambia

Zambia's position as a major copper producer is of long standing. Sharing the rich deposits of the copperbelt with Zaire, Zambia produces all of its copper as principal product. In 1961, with production of 575 thousand tonnes, Zambia was the western world's second most important source of mined copper. As Figures 2.2.6a and 2.2.6b indicate, however, Zambia's output grew very little over the decade to 1976, and has since declined appreciably, resulting in a steady erosion of market share since the mid-1960s.

Zambia's copper output suffered greatly from a massive cave-in at the giant Mufulira mine in 1970; the mine's production at the end of 1973 was still below its level prior to the disaster. Strikes were also a factor depressing output in the early 1970s. In addition, since the nationalization of the industry and the closure of the Benguela railway in 1975, the Zambian industry has been severely hampered by poor management and lack of essential inputs.

Zambia is unparalleled in its dependence on revenue from copper exports. Since 1961, about 90% of export earnings have come from copper. While the importance of copper to the other major producers has shown a tendency to

Figure 2.2.6a

Zambia

Production of Mined Copper

(thousands of tonnes)

Source: MBMS, World Metal Statistics.

Figure 2.2.6b

Zambia

Market Share

(Western World Production of Mined Copper)

decline over the past 15 years, this trend is only barely in evidence in the case of Zambia. Copper shipments represented roughly 84% and 79% of 1984 and 1985 export revenues respectively. In 1982, mining accounted for 20% of gross domestic product (GDP) and one third of government revenue.

2.2.7 Rest of Western World

Other important western world producers of copper are South Africa and Namibia, the Philippines, and Australia, each of which supplied a little under 4% of the western world's output from 1961 to 1984. Mexico, Yugoslavia and Papua New Guinea have also produced significant quantities in the last decade. The total production and market share of the rest of the western world's producers is shown in Figures 2.2.7a and 2.2.7b.

Expansion of output in this group was particularly vigorous in the early 1970s, and again showed strength in the early 1980s, when the output of the major non-Latin American countries was static or falling. As a consequence, these suppliers gained market share at the expense of the established producers to 1983, with a slight dip evident in the depressed years of 1984 and 1985.

Figure 2.2.7a

Rest of Western World

Production of Mined Copper

(thousands of tonnes)

Source: MBMS, World Metal Statistics.

Figure 2.2.7b

Rest of Western World

Market Share

(Western World Production of Mined Copper)

2.3 Price

Throughout the 1961 to 1984 period, there have been two principal pricing systems in existence in the copper market: producer pricing and free market pricing. The relative importance of the two has varied over time.

The producer pricing system, now of (increasingly limited) significance only in North America, is a system characteristic of a relatively concentrated market. Under this system, producers have, in the past, set price at a level considered to be a long-run equilibrium (allowing, one would expect, for a reasonable return on investment), and then produced an amount calculated to satisfy demand at that price.¹⁸

The bulk of western world production was sold at producer prices for a period in the early 1960s, but the system broke down under the pressure of a substantially higher free market price in 1966, and producer pricing has been in retreat ever since. The adjustment of producer

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See F.M. Fisher, P.H. Cootner and M.N. Baily, "An Econometric Model of the World Copper Industry," Bell Journal of Economics and Management Science 3:2 (Autumn 1972), p. 570.

prices to match free market levels is becoming increasingly frequent, and pronounced divergences between the two have become extremely rare.

There are three principal free markets for copper: the London Metal Exchange (LME); the New York Commodities Exchange (COMEX); and the New York merchant market. Of these three, the LME is the most significant in free market pricing. Trades on the LME are carried out by member firms acting as principals in two price-fixing sessions daily, followed by a period of "kerb" dealing. Although physical transactions through the LME are estimated to account for only 5 to 10% of world trade in copper, by far the greatest part of all trade is carried out according to LME-based formulas.¹⁹ The existence of the LME and COMEX have ensured that price quotations closely reflecting changes in physical market balance have been available on a continuous basis for decades.

Figure 2.3.1 shows Western world production and consumption (including net exports to the CPEs) of refined copper from 1961 to 1985. As is evident from this graph, the copper market of the 1960s was characterized by a

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UNCTAD, The Promotion of Multinational Enterprises of Developing Countries: Production and Marketing of Copper by Developing Countries (Geneva: 1983) pp. 28-30.

Figure 2.3.1

Refined Copper Market Balance

Western World Production and Consumption

(thousands of tonnes)

Note: Consumption includes net exports to CPEs.

Source: MBMS, World Metal Statistics.

Figure 2.3.2

Refined Copper Inventories

Western World Year-End Total

(thousands of tonnes)

Source: MBMS, World Metal Statistics.

reasonably close match between supply and demand. During the 1970s and early 1980s, however, greater economic turbulence has resulted in alternating periods of large surpluses and deficits. Inventories (shown in Figure 2.3.2) grew very substantially in the mid-1970s. After a period of drawing down at the end of the decade, they rose again during the 1982-83 recession. These higher stock levels have been reflected in copper prices. Figure 2.3.3 shows the resulting pattern of LME average annual quotations, measured in the inflation-adjusted currencies of the major consuming countries.²⁰

Figure 2.3.3

Copper Price

Average in Consuming Countries

(Index: 1980 = 100)

Note: Series is a consumption-weighted average of domestic price series, deflated by respective GDP deflators.

3 The Effects of Exchange Rate Changes on Competitiveness

3.1 Exchange Rate Changes and Costs

A principal characteristic distinguishing commodity markets from other markets, such as those for manufactures, is the homogeneity of the product. In a well-integrated, transparent market for an undifferentiated good like copper, the price elasticity of demand faced by an individual producer is extremely elastic -- that is, each supplier is a price taker. Although the costs incurred by miners for the smelting and refining of their product is influenced by conditions in the market for copper concentrate, these costs are a relatively small component of the value of a pound of refined copper. Conditions in the refined copper market are therefore reflected quickly in the price a mine receives for its output, and the margin between this price and the mine's cost of production is a critical determinant of the miner's desire and ability to maintain output.

The exchange rate of the country in which the mine is located is one of the most important influences on this margin. Changes in the exchange rate which are not offset by changes in domestic price levels have the effect of

altering the relationship between the prices of goods and services that are traded internationally and the prices of those that are not (this relationship is often referred to as a country's "internal terms of trade"). The copper produced by a mine falls unambiguously within the former category: the price of copper is internationally determined. On the other hand, many of the inputs necessary to the production of copper -- labour in particular -- are in the latter category: their prices are domestically determined.

From the point of view of an outside observer, a change in the exchange rate not offset by changes in domestic prices will appear to leave the price of copper unchanged, while altering the mine's cost of producing it.²¹ A devaluation will lower costs relative to price, increasing a mine's margin, while an increase in the value of the domestic currency will have the opposite effect.

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In a discussion of this sort, it is important to adopt a consistent frame of reference. Because the effects of exchange rate changes in more than one producer are being compared, the standpoint of an outside observer is easier to adopt, and exchange rates and production costs will generally be referred to in US dollars, regardless of the country being investigated. The substance of the analysis would not differ if the changes were described from the domestic point of view from each country in turn, but the discussion would be a great deal more confusing.

The extent to which currency movements affect the profitability of a given country's mining industry depends on the degree to which they affect input costs. This depends on a number of factors, the most obvious of which is the proportion of industry inputs that is actually imported. Table 3.1.1 shows estimates, from Brook Hunt and Associates, of the importance of domestically sourced items in the operating costs of various national copper industries in 1984.

Table 3.1.1 Domestically Sourced Component
of Operating Inputs in Major Copper
Producers (1984)

United States	100%
Canada	80%
Chile	59%
Peru	58%
Mexico	52%
Zaire	37%
Zambia	35%
RSA & Namibia	68%
Philippines	51%
Australia	77%

Source: Brook Hunt, Western World Copper Costs and Production Strategy 1975-85 (London: 1984) p. 89.

The degree to which margins are actually affected by exchange rate changes, however, is overstated somewhat by this table. Interest payments on foreign currency-denominated debt are an important component of costs in many countries, and the burden of these payments relative to copper prices will not be altered by changes in the value of the national currency.

Also of significance is the degree to which inputs consist of "tradeable" (as opposed to actually traded) goods, the prices of which will tend to adjust quickly to offset the exchange rate change.²² Further complicating the issue is the possibility that prices of various items that would otherwise fluctuate in response to exchange rate changes may be controlled by governments.

Notwithstanding these qualifications, however, the short run impact of currency movements on the financial position of the industry can be substantial.²³ The next section provides illustrations of this process, and examines the way in which currency movements can affect the relative positions of producers in different countries.²⁴

22 This would be the case, for example, for Canadian copper mines using oil from Alberta. While the oil is domestically produced, its price is set primarily in international markets.

23 In a 1981 study, the Department of Energy, Mines and Resources calculated that a 10% rise in the exchange rate would lower the metal mining industry's after-tax return on equity by almost 6% (Department of Energy, Mines and Resources, Mineral Policy: A Discussion Paper (Ottawa: 1981) p. 40).

24 It should be noted that this discussion is concerned only with the short run. In the short run, capital costs are sunk, and our primary concern is with the ability of a producer to finance input purchases and minor expansions from cashflow. The effects of exchange rate changes on long run investment decisions are likely to be much smaller, partly because the cost of capital is internationally determined, and partly because long-run decisions would likely be taken with some sort of equilibrium level of the exchange rate in mind, and would not be much influenced by short run fluctuations.

3.2 Exchange Rate Changes and the Supply Curve

The effects of exchange rate changes on a national industry, and on the industries of competing countries, can be examined with the help of partial equilibrium diagrams such as Figures 3.2a and 3.2b. Figure 3.2a depicts an initial equilibrium situation in a hypothetical simplified mineral commodity market. The vertical axis represents cash costs or price in the currency of a third country, the United States; the horizontal axis indicates quantities produced and consumed annually.

Figure 3.2a

A large proportion of productive capacity in this market exists in two countries, A (dotted) and B (cross-hatched). Each country contains three mines, identified in the diagram as A1, A2, etc., each with a capacity of 10 million pounds per year. The costs of production of these mines are indicated by the heights of their respective rectangles.

In the first year, the currencies of Countries A and B are at par with the US dollar -- that is, Country A's national currency unit (NCU) equals US\$1.00, as does Country B's. Production costs at mine A1, for example, are 0.4 of a Country A NCU per pound, which translates to US\$0.40, while production costs at mine B1 are 0.6 of a Country B NCU, or US\$0.60. Assume, in addition, that each mine's costs have a fixed component equal to US\$0.05 per pound, and -- for the sake of simplicity -- that each mine's expenses are incurred exclusively in domestic currency.

These producers, along with a few others, make up the stepwise supply curve (S). The supply and demand (D) curves intersect at 100 million pounds, and price is in equilibrium at US\$0.70 per pound. The cashflows of the various mines in both countries are as represented in Table 3.2a.

Table 3.2a

Country A and Country B:
Hypothetical Cashflows before Devaluation by Country B
(US\$ millions)

	Country A				Country B			
	Mine			Total All Mines	Mine			Total All Mines
	A1	A2	A3		B1	B2	B3	
Revenue	7.0	7.0	7.0	21.0	7.0	0.0	0.0	7.0
Cash Cost	4.0	5.0	7.0	16.0	6.0	0.5	0.5	7.0
Cashflow	3.0	2.0	0.0	5.0	1.0	(0.5)	(0.5)	0.0

Now assume that, in the next year, Country B experiences a massive devaluation, with the value of its currency falling from US\$1.00 to US\$0.50. If the internal price level in Country B remains stable, and the domestic currency cost of producing a pound of commodity does not change, this will have the effect of cutting US dollar costs at each of its mines by half. For example, mine B1 still produces the commodity at 0.6 of an NCU per pound, but this cost now translates to only US\$0.30.

The effect of this change is to alter the supply curve to the shape shown in Figure 3.2b. The position of the mines in Country B, and therefore of Country B's industry as a whole, is dramatically improved. All of Country B's mines now have variable production costs below the market price, and therefore find it desirable to

Figure 3.2b

produce. (The fixed component of cost makes it preferable for B3 to operate at breakeven prices than to lie idle.)

It should be noted that, in the new equilibrium position, price has fallen. (Quantity demanded has also increased.) As a consequence, the industry in Country A finds itself in a worse position. Mine A1's margin on production has shrunk by two thirds, and mine A2 is just breaking even. Although Mine A3's costs have not changed, it will lose so much money by producing that it is better off to close down. The new cashflow situations of the various producers are depicted in Table 3.2b.

Table 3.2b

Country A and Country B:
Hypothetical Cashflows after Devaluation by Country B
(US\$ millions)

	Country A				Country B			
	Mine			Total All Mines	Mine			Total All Mines
	A1	A2	A3		B1	B2	B3	
Revenue	5.0	5.0	0.0	10.0	5.0	5.0	5.0	15.0
Cash Cost	4.0	5.0	0.5	9.5	3.0	4.0	5.0	12.0
Cashflow	1.0	0.0	(0.5)	0.5	2.0	1.0	0.0	3.0

It is essential to note that the change just depicted depends on a stable internal level of prices and costs in Country B. To the extent that the cost of producing a pound of commodity in Country B NCUs rises during the devaluation, the contrast between the situations preceding and following the devaluation will be less pronounced. If, as the theory of purchasing power parity would suggest, the domestic currency costs of Country B's mines had doubled at the same time that the exchange rate depreciation occurred, the cost to Country B's mines of producing the commodity, expressed in US dollars, would be exactly the same as at the outset. There would be no change in the competitive position of either country, and no alteration in the shape of the supply curve.

The real effective exchange rate indexes shown in the following chapter represent an attempt to measure the net effects of exchange rate and domestic cost changes on the

position of each of the six major copper producers relative to its competitors. The indexes measure the inflation-adjusted exchange rate of each country against a harmonic production-weighted average of the exchange rates of all significant producers. Their construction is described in the appendix.

4 Exchange Rate Developments among the Major Producers

This chapter shows the real effective exchange rates of the six major copper producers against other participants in the copper market. The discussion covers the steps involved in producing the exchange rate indexes by reviewing trends in each country's inflation and the nominal and real exchange rates of its currency against the US dollar. In addition, the resulting course of LME copper prices measured in domestic currencies is illustrated.

4.1 The United States

The inflationary experience of the United States is shown in Figure 4.1.1, which illustrates year-over-year changes in the US GDP deflator since 1961. Like much of the rest of the world, the US experienced a steady acceleration of inflation during most of this period. From just below 1% in 1961, the rate of US inflation increased to 5.6% in 1970, and then to 9.3% in 1975. A slight fallback accompanying the post-oil shock economic slowdown was followed by a renewed surge. Inflation peaked at 9.6% in 1981, before it was brought back down by stringent monetary policies and a strong dollar. By 1985, the internal purchasing power of the US dollar had fallen to less than one third of its 1961 level.

The LME price of copper in real (GDP deflator-adjusted) US dollars is illustrated in Figure 4.1.2.²⁵ The variability of copper prices in US dollars has been

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Recall again that the reference to real domestic currency prices involves a change in frame of reference. The real copper prices show the trend in the international price of copper relative to the general price level of the United States (and, presumably, relative to US costs of production also).

United States

Year-over-Year Changes
in GDP/GNP Deflator

Source: IMF, International Financial Statistics.

Figure 4.1.2

United States

Real Copper Price in Domestic Currency

(Index: 1980 = 100)

slightly above the average among the major producers.²⁶ Despite the fact that the 1970s are usually remembered as a decade of rising commodity prices, the inflation adjustment reveals the overall trend in real US dollar copper prices since the mid-1960s to be clearly downward. The severe depression of copper prices in US dollars during the 1982-85 period is the most obvious factor in the dramatic fall in US copper output during those years.

A comparison of this graph with the profile of prices in consuming country currencies shown in Figure 2.3.3 confirms that this trend is common to measurements made in the currencies of other major developed countries. It is interesting to note, however, that the extent of the decline has been smaller in US dollars: the 1985 real US

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The variability of copper prices in various currencies is calculated by estimating an ordinary least squares time trend, calculating the differences between the annual price observations and their trend values as percentages of the trend values, and summing the differences, disregarding signs. (This is similar to the variability measure used in the joint IMF and World Bank study, The Problem of Stabilization of Prices of Primary Products [Washington: 1969], p. 37.) Expressing the resulting variability measures for the eleven most significant producers in index form, with the average for the eleven serving as a base, yields the following values of relative copper price variability:

Australia	97.7	RSA & Namibia	91.1
Canada	103.6	United States	104.2
Chile	100.6	Yugoslavia	108.5
Mexico	92.4	Zaire	145.5
Peru	83.5	Zambia	67.7
Philippines	105.3		

dollar price of copper was a little more than two thirds below the 1966 peak, but measured in deflated Japanese yen, the decline was closer to four fifths.

Both the nominal and the real exchange rates of the US dollar against itself are, of course, unchanging but its real effective rate against other copper suppliers has shown considerable fluctuation. The index of the US real effective exchange rate against producers is shown by the bold line in Figure 4.1.3. If a trend over the two decades to 1980 can be identified, it is slightly downward. Since 1980, however, the American real effective exchange rate

Figure 4.1.3

United States

Real Effective Exchange Rates

(Indexes: 1980 = 100)

against other producers has skyrocketed, suggesting a severe loss of competitiveness.

The real effective exchange rate against consumers is also shown in this chart. This line makes it clear why copper prices fell less in US dollars than in the currencies of other consumers over the period: the steady decline in the inflation-adjusted value of the US dollar against other consumer currencies mitigated the decline in the price of copper. It is interesting to note that while the US dollar rose to unprecedented heights against the currencies of its copper-producing rivals from 1983 to 1985, it had merely returned to the levels of the early 1970s when measured against the currencies of copper consumers.

4.2 Canada

Trends in Canadian inflation are shown in Figure 4.2.1. The general pattern of Canada's experience since 1961 has been similar to that of the United States, but Canadian inflation has been slightly worse than that of the US, with year-over-year changes in the GNP deflator exceeding 10% in six of the nine years from 1974 to 1982. As the theory of purchasing power parity would suggest, one result of this discrepancy was a decline in the Canadian nominal exchange rate against the US dollar (shown in index form in Figure 4.2.2).

Figure 4.2.3 illustrates Canada's real exchange rate against the US dollar. It is apparent from this series that, after having appreciated steadily in real terms since 1962, the Canadian dollar declined against the US dollar after 1976 by more than inflation differentials would indicate. As a consequence, the fall in the international price of copper since 1973-74 has been somewhat less pronounced when measured in real Canadian dollars than in real US dollars. Nevertheless, as is shown by Figure 4.2.4, the general pattern of copper prices in the two countries has been similar.

Figure 4.2.1

Canada Year-over-Year Changes in GDP/GDP Deflator

Source: IMF, International Financial Statistics.

Figure 4.2.2

Canada Nominal Exchange Rate against US Dollar (Index 1980 = 100)

Source: IMF, International Financial Statistics.

Figure 4.2.4

The Canadian real effective exchange rate index against other copper producers (as well as the index against consumers) is shown in Figure 4.2.5. The general outline of the Canadian dollar's movements against the currencies of other copper producers is not very dissimilar to that of its US counterpart. The fall in the index (indicating an advantage to Canadian copper mines) around the turn of the decade is more pronounced, however, because of the relative strength of the Canadian dollar in the early to mid-1970s. Since 1980, the real value of the

Figure 4.2.5

Canadian dollar against the currencies of all copper producers except the US has risen. Canada's competitive position has -- like that of the US -- suffered markedly, with the deterioration continuing in 1983-85, even as the Canadian dollar's upward trend relative to consumers was first slowed and then reversed.

4.3 Chile

Like many Latin American countries, Chile's monetary performance during the last two decades has not been very good, and double-digit inflation has been the norm (see Figure 4.3.1). In the Chilean case, however, a particularly dramatic deterioration in monetary policy occurred during the presidency of Salvador Allende in the early 1970s. Inflation soared from 33% in 1971 to nearly 700% in 1974, and was not brought back down below triple digits until 1978. By 1985, the internal purchasing power of the Chilean peso had dwindled to about one two-thousandth of

Figure 4.3.1

Source: IMF, International Financial Statistics.

one percent of its 1961 level. This debasement was matched by a plunge in the external value of the peso, as the nominal exchange rate index in Figure 4.3.2 shows.

The combined effect of inflation and nominal exchange rate changes has been a real exchange rate against the US dollar that has been far from stable.²⁷ The Chilean peso dropped to an inflation-adjusted low against the US currency in 1975. By 1977-78, it was back to the levels of the pre-Allende period (Figure 4.3.3). One of the principal instruments by which Chile's economic managers tried to squeeze inflation out of the economy in the late 1970s was the maintenance of a fixed exchange rate against the US dollar. Because domestic inflation remained above the US rate, however, the peso steadily appreciated in real terms, and by 1980 it was almost twice as high as it had been five years earlier. Since then, international economic developments have forced a number of large devaluations.

The effect of these monetary developments has been an LME copper price profile in real Chilean pesos (Figure

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It is necessary to be wary of some of the early numbers used in this calculation. This is because the enormous changes in the magnitude of the exchange rate and price deflator series over the period cause problems with the number of significant digits in early observations.

Figure 4.3.2

Source: IMF, International Financial Statistics.

Figure 4.3.3

4.3.4) that differs somewhat from those in US and Canadian dollars. The appreciation of the real exchange rate during the latter 1970s produced an erosion in peso copper prices considerably more severe than that experienced by the North American producers. On the other hand, however, prices in Chile since 1982 show a recovery, while in the US and Canada, they have continued flat or falling. Although the importance of copper to the Chilean balance of payments would suggest that Chile's real exchange rate should move in the same direction as copper prices, this tendency is not much in evidence. The variability of LME copper prices measured in deflated pesos has been almost exactly equal to the average of the six big producers.

Chile's real effective exchange rate against other copper producers is illustrated in Figure 4.3.5. This graph suggests that Chile's domestic costs were highest relative to those of its competitors in the early 1970s and again in the early 1980s. Since the abandonment of a fixed rate against the US dollar in 1982, the Chilean peso has depreciated substantially vis-a-vis the currencies of other suppliers, suggesting an augmentation of Chilean competitiveness.

Figure 4.3.4

Figure 4.3.5

4.4 Peru

A review of the course of price inflation in Peru since 1961 (Figure 4.4.1) leads to the observation that a reasonably good performance through the 1960s was followed by a loss of control by the Peruvian monetary authorities during the 1970s, with the advent of more difficult world economic circumstances and the growth of Peru's oil exports. As Peru's money has depreciated internally at an increasing rate, ever-larger declines in the nominal exchange rate (Figure 4.4.2) have occurred.

Peru's real exchange rate against the US dollar is illustrated in Figure 4.4.3. Because the devaluations of the 1960s and early 1970s tended to undercompensate for the differential between US and Peruvian inflation, Peru's real rate showed an appreciating trend until 1975. Substantial devaluation to a low in 1978 was followed by another period (as oil exports grew) when inflation outpaced devaluation. From 1981 to 1985, like that of virtually every other currency in the world, the real value of the Peruvian unit against the US dollar plunged.

It is interesting to note that the real value of the Peruvian currency has tended to be greater during times of strong commodity prices -- though not surprising, given.

Figure 4.4.1

Peru Year-over-Year Changes in GDP/GNP Deflator

Source IMF, International Financial Statistics.

Figure 4.4.2

Peru Nominal Exchange Rate against US Dollar (Index: 1980 = 100)

Log Scale

Source IMF, International Financial Statistics

Figure 4.4.3

Figure 4.4.4

Peru's dependence on natural resource exports. An examination of the course of copper prices measured in inflation adjusted units (Figure 4.4.4) reveals that, although the profile of price movements is similar to that in most other producing countries, the size of annual fluctuations has been relatively small. The variability of LME copper prices has been more than 15% lower in Peruvian currency than in the currencies of the other major producers.

When Peru's real exchange rate is measured against all other copper producers, and not just the US, a different pattern emerges (Figure 4.4.5). Although the real depreciation from 1975 to 1978 likely resulted in an increase in competitiveness, Peru's competitive position eroded over the six years to 1984. The slight decline in the real effective index in 1985 returned it to a level roughly equal to its 1961-85 average.

Figure 4.4.5

Peru

Real Effective Exchange Rates

(Indexes: 1980 = 100)

4.5 Zaire

The course of monetary developments in Zaire since 1961 almost defies description. Political disruptions in the early 1960s and erratic economic management throughout the period have produced a price level performance (Figure 4.5.1) best characterized as extraordinary.

As Figure 4.5.2 indicates, the management of the exchange rate has been equally extraordinary. The timing and magnitude of Zaire's irregular, massive devaluations have borne little relation to inflation differentials. Except for a relatively stable period in the early 1970s, Zaire's real exchange rate (Figure 4.5.3) against the US

Figure 4.5.1

Source: IMF, International Financial Statistics.

Figure 4.5.2

Source: IMF, International Financial Statistics.

Figure 4.5.3

dollar has consequently exhibited enormous fluctuations: in 1985, the dollar value of the Zairean currency -- also called the zaire -- was less than one quarter of its level in 1978, after adjusting for inflation.²⁸

The result of Zaire's unique performance is that LME prices measured in zaires (Figure 4.5.4) have been over 40% more volatile than the average for the six major producers, and their profile bears only scant resemblance to the course of copper prices in other currencies. The general downward trend over the 1970s, punctuated by the 1973-74 price spike, is evident, although much more severe and prolonged. By 1978, the zaire price of copper had declined by almost three quarters from its 1969 level, compared with a decline of less than one half in US dollars over the same period. Since then, however, the general trend of zaire copper prices has been upward, and by 1984-85 the price of copper in Zaire had reached levels comparable to those of the early 1970s.

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As was the case with Chile, the magnitude of the zaire's depreciation over the 1961-85 period causes problems with the number of significant digits in early observations. In addition, it is difficult to have much confidence in statistics on Zairean price levels during the early 1960s, given the political disturbances and fragmented nature of the economy at the time. For these reasons, the exchange rate calculations for the 1961-64 period should be treated with caution.

Figure 4.5.4

Figure 4.5.5

The fluctuations in the value of the zaire have been so large that they dwarf fluctuations in the values of any currency that the zaire is measured against. The trend of Zaire's real effective exchange rates against producers and consumers (Figure 4.5.5) is very similar in appearance to the trend of Zaire's real exchange rate vis-a-vis the US dollar. The index against producers suggests that after a long and accelerating erosion of competitive position from the beginning of the 1970s to 1978, Zaire has improved its standing virtually continuously and very substantially.

4.6 Zambia

By comparison with the experiences of Chile, Peru and Zaire, Zambia's monetary management -- at least until 1983 -- appears exemplary. Figure 4.6.1 shows year-over-year changes in the Zambian GDP deflator. Zambia has had several periods of double-digit inflation, but they have not (so far) been prolonged. It is interesting to note, moreover, that prior to 1983-84, these periods of high inflation tended to correspond to periods of strong copper markets. In periods of weakness such as 1971 and 1975, on the other hand, general price levels in Zambia fell.

Figure 4.6.1

Zambia Year-over-Year Changes in GDP/GNP Deflator

Source: IMF, International Financial Statistics.

The nominal exchange rate of the Zambian kwacha against the US dollar (depicted in Figure 4.6.2) also indicates relatively stable management. After having been pegged to the US dollar since independence, the kwacha floated upward somewhat with the end of the era of fixed exchange rates in the early 1970s. The end of high prices for copper, and continuing high prices for oil, exerted downward pressure on the Zambian exchange rate in the mid-1970s. As world copper markets deteriorated and Zambian inflation started to outpace US inflation significantly, in the 1980s, the kwacha weakened at an accelerating rate.

The result of these trends in inflation and the nominal exchange rate has been a real exchange rate against the US dollar (Figure 4.6.3) that bears a marked resemblance to the course of copper prices in US dollars.²⁹ The inflation-adjusted value of the kwacha against the US dollar has been greatest during periods of copper market strength -- the mid- and late 1960s, 1973-74 and 1979-80 -- and weaker during depressed markets. The fact that Zambia typically depends on copper for 90% of its foreign exchange earnings is the principal factor behind this phenomenon.

29 This does not reflect any peculiarity of US dollar measures. The Zambian real exchange rate against any currency would have a profile similar to the deflated price of copper in that currency.

Figure 4.6.2

Zambia

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Nominal Exchange Rate against US Dollar

(Index: 1980 = 100)

Source: IMF, International Financial Statistics.

Figure 4.6.3

Zambia

Real Exchange Rate against US Dollar

(Index: 1980 = 100)

The profile of copper prices in deflated kwachas (Figure 4.6.4) has a shape similar to that of copper prices in developed country currencies, but fluctuations in the real value of the kwacha have smoothed out the fluctuations in the price of copper about its trend. As a result, the variability of kwacha copper prices has been the lowest among the major producers. Zambia's real effective exchange rates against producers and consumers, shown in Figure 4.6.5, tell a similar story. The influence of the exchange rate on Zambia's competitive position vis-a-vis other producers has been detrimental during periods when the copper market was strong. In times of market weakness, by contrast, the real value of the kwacha has fallen, enhancing the position of the Zambian industry.

2 of/de 2

MICRO

Figure 4.6.4

Figure 4.6.5

4.7 All Producers

Before leaving the description of producers' exchange rates behind, an interesting fact about the real exchange rates of copper producers as a whole (i.e. the harmonic average of the exchange rates of all producers) deserves comment.³⁰ If this aggregation of real exchange rates is measured against the corresponding basket of consumer currencies, thus obtaining a real effective exchange rate of producers against consumers, a pronounced general downward trend over the 1961-85 period is evident. This series is shown in Figure 4.7.1. This long-term decline in producer currencies relative to those of consumers raises interesting questions. Two possible causes suggest themselves.

First, productivity advances in the tradable goods sectors of the European countries and Japan have produced

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It was this series that served as the denominator in the real effective exchange rate indexes of the preceding sections. It would be possible to deal with the remaining producers separately, or in a rest-of-western-world subgroup. It seems better, however, to proceed to a discussion of all producers together, for the sake of space (and in order to avoid such obscurities as weighted averages of inflation rates). By now, the concepts of adjusting exchange rates for inflation and constructing weighted baskets have probably become familiar, and a transition to a discussion of producers as a whole should not be too jarring.

Producers

Real Effective Exchange Rate against Consumers

(Index: 1980 = 100)

wage increases throughout these economies that have progressively raised costs in their non-tradable sectors -- and hence their real (as adjusted by GDP deflators or CPIs) exchange rates -- compared to the less dynamic economies of the copper producers.³¹

In addition to this, the copper market has become more of a buyer's market over time, as is evidenced by the

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This phenomenon, termed the "productivity bias", has led Bela Balassa to criticise the use of purchasing power parity in evaluating the level of an LDC's exchange rate against a developed country at a particular point in time ("The Purchasing-Power Parity Doctrine: A Reappraisal," Journal of Political Economy 72 (December 1964). The point here is similar, except that it is made in the context of relative purchasing power parity over time.

increasing level of inventories illustrated earlier. As a consequence, copper's purchasing power relative to other goods has declined; and producers dependent on copper exports have experienced this deterioration in their terms of trade partly as a decrease in copper prices in their own currencies, and partly as a decrease in the value of their currencies against those of consuming countries. This interpretation is corroborated by the shape of the curve, which exhibits a high degree of correlation with the profile of copper prices in consuming country currencies.

Whatever the precise nature of cause and effect, the shape of this curve has several interesting implications for the copper market, which are discussed further in the conclusion.

5 Testing the Real Effective Exchange Rate Indexes

Having elaborated an index designed to show changes in the competitive positions of national copper industries, it is appropriate to conduct a statistical test to see whether fluctuations in the index have corresponded to changes in quantities produced by the various countries. This chapter tests for such a relationship, using the real effective exchange rate indexes of the six major copper producers in a simple one-equation test.

5.1 The Test

An investigation of the significance of movements of copper producers' real effective exchange rates against each other can be conducted with a one-equation test, applied to each country in turn. Changes in market share are postulated to be a function principally of three factors: changes in the exchange rate vis-a-vis other producers; changes in ore grades and extractive technologies; and disruptions such as strikes and natural disasters. The equation to be estimated is, therefore:

$$\text{SHARE} = a + b_1 \text{REER} + b_2 \text{TIME} + b_3 \text{STRIKE}$$

Where SHARE = the country in question's share of the western world market;

REER = its real effective exchange rate index;

TIME = a time trend, intended to capture the effects of changing ore grades and technological developments; and

STRIKE = an adjustment of each country's market share for disruptions in both domestic and foreign production.

Although the use of market share as a dependent variable and the exchange rate index as an independent variable in such an equation is unusual, this formulation is similar to an approach to the supply side that is common in econometric studies of copper. Equations seeking to explain supply generally treat mine output in each country as a

function of (US dollar) price, a time trend, and strikes.
(Cost and capacity variables are sometimes also included.)

Market share is a variable measuring levels of output, but rather than being concerned with absolute amounts produced by a country, it tracks shifts in production between each country and its competitors. Similarly, the REER variable measures the incentive to produce, but focusses on the relative level of the incentive in each country by comparison with its rivals. Since a rising index indicates a loss of competitive position, this variable can be expected to be negatively correlated with market share in a statistical test. This approach avoids some problems inherent in a model making reference to absolute levels of prices.³²

A couple of noteworthy difficulties remain, however. The importance of byproduct copper in all countries is not the same, and byproduct copper is associated with different

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The estimation of price-driven supply equations is complicated by several factors. Quoted prices may not be representative of the prices at which actual transactions take place. Moreover, the existence of administered prices through part of the period under investigation renders the economic logic of price-determined supply functions dubious (on this latter point, see Mikesell 1979, pp. 175-76). Also of importance, though rarely noted, is the fact that price is also, in part, a function of supply. Because the real effective exchange rate index focusses on changes in margins between countries, rather than the actual level of prices, these difficulties do not arise.

minerals, with different price trends, in the various producers. Another potential problem arises from the possibility that, in a country highly dependent on copper exports, an event could simultaneously lower output and (through the resulting pressure on the balance of payments) the exchange rate, producing a spurious apparent reversal of the expected relationship.

The use of a time trend in this context is very similar to its use in level-of-output equations. Instead of serving as a proxy for the impact of ore grade and extractive technology changes on the output of one country, however, it is here intended to capture the net effects of these changes in all suppliers on the market share of the country under investigation.

Again, the strike variable as used here is not unusual, except that rather than being concerned with the impact of strikes and natural disasters on the production of one country only, it is intended to measure the net effect of all western world disruptions in a given year on each country's market share. The series for each country was produced by estimating the difference between actual market share in a given year and the market share figure that would have been achieved in the absence of any

domestic or foreign disruptions. The expected coefficient for this variable is therefore -1:0.33

One further difference between this equation and other econometric treatments of supply deserves mention. Because decisions to invest in expansions and new projects typically take time and are probably made on the basis of expected prices (which are continually being modified in light of experience) most models of copper supply also incorporate some sort of lag. The most popular -- based on the notion that the impact of a change in price is felt most in the first period, and declines exponentially thereafter -- is the geometric distributed lag, in which the value of the dependent variable (production) in the previous period

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The difficulties involved in producing a series for disruptions are numerous, and necessitate a cautionary note (the sources used in constructing the STRIKE variable are listed in the footnotes to Section 2.2.) Estimates of production lost because of any disruption involve a large amount of guesswork. It is often difficult to ascertain the extent to which a disruption actually affected production, and the amount that would have been produced in the absence of a curtailment is always a matter of conjecture. Things get considerably more complicated when the capacity of a mine changes as a result of a disruption, or if a strike leads to closure -- at what point does the hypothetical undisrupted level of production change? Finally, it should be noted that the effects of disruptions and exchange rate changes can be mingled, not only in the case of simultaneous drops in output and exchange rate referred to earlier, but in the event that an uncompetitively set exchange rate results in slower repairs of, or lower production at, damaged facilities.

appears on the right-hand side of the equation.³⁴

However, for both practical and theoretical reasons, the use of a geometric distributed lag does not seem desirable.

To begin with, the use of the geometric distributed lag has been subjected to considerable criticism, and its estimation presents a host of difficulties.³⁵ There are also grounds for doubting that the effects of changes in the exchange rate vis-a-vis competitors are felt much after the initial year or two. As was argued above, decisions about longer term investments are probably not affected by the exchange rate configurations of the moment. It is in the course of every-day operations that exchange rate fluctuations make a difference to the capacity of copper miners to spend money on replacement parts, maintenance,

³⁴ The geometric distributed lag has been used in copper supply equations in Charles Rivers Associates Inc., An Econometric Model of the Copper Industry (Cambridge: 1970), and in F.M. Fisher, et al., "An Econometric Model of the World Copper Industry," Bell Journal of Economics and Management Science 3:2 (Autumn 1972). Ferdinand Banks explains the derivation of this model and also presents some of his own results (F. Banks, The World Copper Market: An Economic Analysis [Cambridge: 1974], Chapter 8).

³⁵ On the problems involved in estimating equations containing a lagged dependent variable, see P. Dhrymes, Distributed Lags: Problems of Estimation and Formulation (Amsterdam: 1981). The use of geometric distributed lags in supply functions has received considerable criticism, both generally (Z. Griliches, "Distributed Lags: A Survey," Econometrica 35:1 [January 1967] especially pp. 43-44), and in connection with copper market modelling particularly (Mikesell 1979, pp. 171-77).

and other items necessary to continued production. The effects of this type of expenditure -- or the lack of it -- on output are felt relatively quickly. Nevertheless, the possibility of lagged effects cannot be ruled out.

These difficulties, and the uncertainties inherent in all econometric work, must be borne in mind in evaluating the results presented in the next section.

5.2 Results

Equations were estimated from 1961-85 data for the US, Canada, Chile, Peru and Zambia.³⁶ Because of the dubious quality of the exchange rate and STRIKE series for Zaire in the early years, Zaire's estimates are derived from 1964-85 data. The results are displayed with the absolute magnitudes of the t-statistics of the coefficients given in parentheses below each. The apparent elasticity of market share with respect to the exchange rate index (e_{REER}) for each producer is also given.³⁷ The graphs accompanying each equation illustrate the actual and fitted series, after eliminating the influence of lagged residual feedback (represented by ρ) from the fitted curve.

36 The equations were estimated by ordinary least squares, using Mikros Corporation's ESP (IBM PC Version 1.10). ρ (the coefficient of first order correlation of residuals) was estimated by the Cochrane-Orcutt iterative technique. In the case of Zaire, serious auto-correlation did not appear to be present, and the Durbin-Watson statistic (D.W.) is given instead.

37 The elasticities, calculated from the means of the respective series, show the percentage change in market share associated with a one percent change in the value of the real effective exchange rate index. (This figure is shown because the coefficients themselves are subject to arbitrary scaling effects.) In the US case, for example, a one percentage point change in the exchange rate index appears to have been associated with a one fifth of a percent change of market share, in the opposite direction. Since the average amount of copper produced in the US from 1961-85 was about 1.27 million tonnes, and the average level of the US REER index was 118, this could very tentatively be interpreted to mean that a 10% rise in the US REER index has been associated with a transfer of output from the US to competing producers of some 25 thousand tonnes annually.

$$\text{USA SHARE} = 37.743 - 0.039 \text{ REER} - 0.569 \text{ TIME} - 0.892 \text{ STRIKE}$$

(1.487) (6.276) (7.510)

$R^2: 0.913$ $\text{Rho: } 0.554$ $\text{REER: } -0.191$

Figure 5.2.1

$$\text{Canada SHARE} = 12.677 + 0.014 \text{ REER} - 0.136 \text{ TIME} - 1.145 \text{ STRIKE}$$

(0.805) (1.244) (7.651)

$R^2: 0.780$ $\text{Rho: } 0.843$ REER: N.A.

Figure 5.2.2

Chile SHARE = $8.363 - 0.017 \text{ REER} + 0.522 \text{ TIME} - 0.925 \text{ STRIKE}$
 (0.781) (2.798) (3.163)
 $R^2: 0.847$ Rho: 0.854 $\rho_{\text{REER}}: -0.095$

Figure 5.2.3

Peru SHARE = $6.168 - 0.026 \text{ REER} + 0.107 \text{ TIME} - 1.300 \text{ STRIKE}$
 (3.291) (4.320) (4.082)
 $R^2: 0.851$ Rho: 0.552 $\rho_{\text{REER}}: -0.629$

Figure 5.2.4

$$\text{Zaire SHARE} = 7.899 - 0.008 \text{ REER} + 0.024 \text{ TIME} - 0.499 \text{ STRIKE}$$

(1.479) (1.560) (1.248)

R²: 0.287

D.W.: 1.618

*REER: -0.093

Figure 5.2.5

Zairean Market Share: Comparison of Actual and Fitted values

$$\text{Zambia SHARE} = 21.163 - 0.025 \text{ REER} - 0.431 \text{ TIME} - 0.755 \text{ STRIKE}$$

(1.447) (10.737) (4.864)

R²: 0.959

rho: 0.507

*REER: -0.205

Figure 5.2.6

Zambian Market Share: Comparison of Actual and Fitted values

These results provide some support to the hypothesis that the changes in competitive position measured by the real effective exchange rate indexes are reflected in quantities produced. The coefficient of the index is of the expected sign in the equations for five of the six producers -- Canada being the exception -- and is significant at the 90% level or better in four of them.³⁸ In addition, with the exception of Zaire, the fit of the regressions is quite good. The equations for the US, Chile, Peru and Zambia account for over 80% of the variation in the market shares of those countries.

The positive (though not statistically significant) coefficient obtained for the REER index in the case of Canada is, from the standpoint of this analysis, surprising. The proportion of inputs to Canadian mining that is domestically priced is high and, in Canada's case, data on price levels can be assumed to be good. Canada's market share and its exchange rate against other producers were both relatively high in the mid-1970s. Also anomalous is the recovery of market share in 1983 and 1984, even as the real exchange rate against other producers continued to

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Because of the unexpected sign of the real effective exchange rate coefficient in the Canadian case, it is difficult to say what meaning -- if any -- could be attached to an elasticity calculation. Accordingly, none is given.

appreciate. A possible explanation lies in the unique importance of byproduct copper in Canadian output. The addition of price series on gold, nickel and zinc might produce less unexpected results.

It should be noted that the equation obtained for Zaire is quite weak, failing particularly to account for the strength of Zairean production relative to its competition in the first half of the 1970s. In addition, the distance of the STRIKE variable from its expected value of -1.0 is bothersome, because the relationship between this series and market share should be absolutely straightforward. It probably reflects the relative lack of data on the impact of disruptions on Zairean production, and possibly also an overestimation of the effects of those, such as the 1978 invasion, that are known. (Similarly, the high coefficient obtained for Peru may reflect underestimation of the impact of disruptions.) The use of a more complete and accurate disruption series might cause different coefficients to be obtained for the other variables in the equation.

Another result that should be treated with some caution is the high exchange rate coefficient obtained for Peru. This figure is in part a consequence of the start-up of the large Cuajone pit in 1976 and the Cerro Verde project in 1977, just as the Peruvian currency commenced a

steep decline from the overvalued levels of 1973-75. The timing of these projects is unlikely to owe much to exchange rate management. Nevertheless, the performance of the equation over the rest of the period suggests a degree of correlation between the exchange rate index and Peru's market share.

One final unexpected result is worthy of mention: the lack of correlation between sensitivity to exchange rate changes and copper industry self-sufficiency (see Table 3.1.1). One would expect the impact of exchange rate changes to be felt most in countries like the US and Canada, where inputs are domestically sourced and priced, and felt least in countries like Zambia, where most inputs are priced (like the product) in international markets. This finding is discussed further in the next section.

6 Conclusion

6.1 Implications

Among the more interesting of the discoveries to emerge from this study is the long term decline of producer exchange rates against those of consumers over the last two and a half decades. Two likely contributing factors to this phenomenon were mentioned in Chapter 4: higher price levels in the more developed consumers as a consequence of wage pressures in their non-traded goods sectors; and the declining terms of trade of copper producers as a result of deteriorating market conditions.

Whatever the precise causes of the trend, it does point to one feature of the copper market which is likely to be found in markets for other primary commodities as well. It is a familiar proposition in economics that the long-run equilibrium price of a commodity is that price just high enough to induce sufficient new investment to meet incremental demand.³⁹ The overall trend in copper price appears to be downward in all currencies, suggesting

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In studies of the copper market, analysis of this type is primarily associated with Orris Herfindahl (Herfindahl 1959).

falling costs of production. It is interesting to note, however, that -- as a result of the real depreciation of producer vis-a-vis consumer currencies -- production costs could be said to have fallen faster from the standpoint of consumers, particularly in Europe and Japan.

A second observation of note is the correlation between market share and the real effective exchange rates of producers against each other. This appears to lend support to the hypothesis that exchange rate changes are reflected in quantities produced, thus providing additional evidence about the importance of proper exchange rate management, and suggesting that exporters dependent on a few commodity exports might do well to keep an eye on exchange rate developments in their competitors.

This correlation also suggests that the analysis of copper price movements could be improved by making reference to changes in producer exchange rates.⁴⁰ There

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This approach has been followed explicitly by RSI in one of their econometric models of the world copper market. Their price determination equation makes use of a cost variable, which is a weighted average of producer country real exchange rates against the US dollar, to explain US dollar prices. It is interesting to note that RSI does not use exchange rate- and inflation-related variables in the country supply equations themselves, indicating that RSI assumes that these changes affect price immediately, rather than through their effects on quantities produced. Most analyses of the effects of exchange rate changes on commodity prices assume that price changes are

is some evidence to support the view that mineral exporters are more susceptible to inflation and have a greater tendency toward indebtedness than other LDCs.⁴¹ If this is so, the link between exchange rate movements and fluctuations in output suggests that the resulting instability in mineral exporters' exchange rates could be a source of volatility in the copper market, and perhaps those of other minerals as well.

These two observations together suggest a third. The relationship between producer exchange rate movements and copper market developments is obviously not simply one of cause and effect. As is suggested by the similar profiles of producer exchange rates generally (and that of Zambia specifically) and copper prices, the strength of copper

effected through changes in quantities supplied and demanded. (See, for example, M. Radetzki, "Effects of a Dollar Depreciation on Dollar Prices in International Commodity Markets," Resources Policy [September 1985].) Indeed, price changes must come about because there is at least a possibility that changes in quantity will occur, since the effectiveness of competitive bidding on the part of a devaluer depends on his being able to step in and replace the output of the producer he undercuts.

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Gobind Nankani cites Chile, Zambia and Zaire as examples of the greater susceptibility of mineral exporters to inflation, which he explains as a consequence of export and fiscal earnings instability, spill-over effects from mining sector wage rates, and bottlenecks in the supply of non-tradable items during mineral booms. G. Nankani, Development Problems of Mineral-Exporting Countries, World Bank Staff Working Paper No. 354 (New York: 1979) pp. 36-42. On greater susceptibility to indebtedness, see pp. 49-51.

producers' currencies is affected by the purchasing power of their exports. When the copper market is weak, the currencies of producers most dependent on it will sink, increasing their competitiveness relative to their less copper-dependent counterparts; when the market is strong, the reverse will occur.

From the standpoint of observers in a country such as Canada or the US, there is something of a vicious circle in this phenomenon. If producers in countries highly dependent on copper exports are prevented from feeling the full effects of weakness in the market because of movements in their exchange rates, glutted markets may take longer to stabilize. Similarly, in times of boom, incentives to produce more will not be felt as keenly in many important copper producing economies.⁴² From the standpoint of a Chilean or a Zambian, the circle has more of a virtuous aspect -- the burden of adjusting to market conditions will fall more heavily on countries to which the copper industry is less essential. Whatever the merits of the various points of view, this effect would tend to render much of the world's productive capacity less responsive to market conditions, producing greater volatility of (consuming country currency) prices for a given fluctuation in demand.

⁴²

This is similar to the conclusion reached by Gelb with regard to the coffee market (Gelb 1974).

The likely responsiveness of producers' exchange rates to copper market conditions also necessitates a cautionary note regarding the results presented in the previous section. There is a possible alternative explanation for the negative REER coefficient, along the following lines -- with Zambia offering a striking example.)

As far as its external balance is concerned, Zambia is very close to being a one-industry country. Virtually all it can produce (in the short run) is copper, and it is always in its interest to produce as much as possible. When copper prices are high, greater production is induced elsewhere; but Zambia is already producing at capacity, so the only effect on it is an appreciation of its real exchange rate -- and a smaller share of the copper market. Low copper prices cause cutbacks in the rest of the world as resources are shifted elsewhere; Zambia cannot reduce production, however, so the only effect is a lower exchange rate -- and increased market share. Thus an inverse correlation between the level of the exchange rate and market share is observed, but not because of the sequence of cause and effect that inspired the econometric test.

One observation supporting this alternative explanation is the lack of correlation between exchange rate sensitivity and industry self-sufficiency noted earlier. There can be little doubt that an industry's dependence on

imports will affect the degree to which it benefits from a devaluation. In the case of copper, however, those countries whose industries are less self-sufficient tend to be more dependent on copper exports. The influence of copper market conditions on the exchange rate may be so strong that the extent to which import dependency reduces the copper industry's sensitivity to exchange rate changes is relatively insignificant.

6.2 The 1980-85 Period

With their extraordinary exchange rate movements and commodity market imbalances, the years since 1980 offer an especially good example of the interaction between exchange rates and copper market conditions.⁴³ If the 1970s will be remembered as a period of commodity boom with threats of shortage on every front, the first half of the 1980s is likely to be recorded as a period of excess supply and depressed prices for most commodities that rivals the worst historical experience. The copper market will be a prominent exhibit in this record.

As was illustrated in Figure 2.3.3, copper prices started the 1980s in a period of strength, which punctuated an overall downward trend that had lasted since the mid-1960s. Figure 6.2.1 shows the weighted average price in inflation-adjusted consuming country currencies, on a

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Sources for copper market developments during this period are Metals Week, Mining Journal, Metal Bulletin Monthly, Minerals and Materials: A Bimonthly Survey and Engineering and Mining Journal, as well as corporate annual reports and public statements. Balance of payments data are from the IMF's International Financial Statistics; data on debt service are from the American Express International Banking Corp., International Debt: Banks and the LDCs (London: 1984).

Figure 6.2.1

Copper Price

Average in Consuming Countries

(Index: 1980 Q1 = 100)

Note: Series is a consumption-weighted average of domestic price series, deflated by respective CPIs.

quarterly basis, since the beginning of the decade.⁴⁴ The price of copper was high at the beginning of 1980, boosted by speculation and spillover from precious metals markets. After peaking around US\$1.40 in the early spring, free market prices began a sharp decline, as interest rates and exchange stocks rose, while precious metal prices sub-

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This price series was constructed in a fashion analogous to that of the consumer price series shown earlier, with the following modifications: domestic prices have been deflated by CPIs, since quarterly GDP deflators are not available for many of the countries; and the weights are based on market share over the years 1980-85. Similar changes were made in the calculation of the real effective exchange rates for producers shown below. The source for the figures is the IMF's International Financial Statistics, with spot rates for the latest quarter taken from the Globe and Mail (16 August 1986 and 18 August 1986). Estimation of inflation rates was necessary for the calculation of some of the latest observations.

sided.⁴⁵ The price settled in the high 80 cent range in April, and then fell further to finish the year below 80 cents. Western world consumption of refined copper, though down from the strong figures of 1979, exceeded production by a small margin over the year, leading to a slight decline in world stocks for the third year running.

1981 saw a significant deterioration in the market, however. A continuation of the downward slide of prices was temporarily reversed in late March, but demand weakened at an accelerating rate toward the end of the year, and US dollar price -- further depressed by the dollar's interest rate-fuelled rise -- fell into the low 70s. In 1982, with the onset of a severe economic slump world-wide, demand for copper fell dramatically, down 6.6% year-over-year. Price continued to weaken throughout the first half of the year, to reach the mid-50s by June. Declining interest rates raised prices briefly in the summer, before they dropped again in autumn amidst considerable volatility.

Despite a temporary improvement in price at the beginning of 1983, with a stabilization of interest rates, a pause in the rise of the US dollar, and the beginning of

⁴⁵ Except as noted, all price and cost quotations in this section are in US dollars per pound.

economic recovery in North America, copper stocks continued to rise. Inventories closed the year near 1.67 million tonnes (equal to nearly one quarter of western world consumption), while price stagnated in the low 60s. In 1984, with the recovery spreading to Europe and Japan, consumption grew substantially, rising almost 11% over the previous year. A rapid drawing down of stocks early in the year prompted prices to move back up around 70 cents in April, but a slump back to the low 60 cent range in the summer was followed by a dramatic drop to the mid-50s in August. Despite a drop in inventories of almost half a million tonnes by the end of the year, US dollar prices barely moved over 60 cents by the end of the year.

The market was again showing signs of strength in early 1985, as stocks continued to decline, and the US dollar finally peaked. Inventories reached three-year lows in the spring, lifting prices back up to the 70 cent range, and shortages produced periods of "backwardation" on the LME in May and again in July.⁴⁶ During the summer, however, weaker demand and a rapid buildup of stocks combined with the collapse of the International Tin

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Backwardation is a term signifying the unusual situation in which exchange prices for immediate delivery are at a premium to those for future delivery. (The normal situation, in which near term contracts are relatively less expensive, is termed a contango.)

Agreement to push price back down around 60 cents. Although 1986 continued the pattern of rallies early in the year, rising production and flat demand further depressed the market. By mid-summer, price had again fallen below 60 cents. Over three years into the recovery, the price of copper continued to bump along at levels not far removed from those plumbed in the trough of the recession in 1982.

6.2.1 The United States

This period was an extremely bleak one for the copper industry in the United States, with the decline in its fortunes symbolized by the fall of the US from first place among western world copper producers. The poor years ahead were not evident at the start of the decade -- the first quarter of 1980 was the most profitable in the industry's history. However, the summer of 1980 saw both a weakening of the market and the beginning of a massive strike which by August had virtually paralyzed the industry. By its end, 20 weeks later, it had cost US producers somewhere not far short of 400 thousand tonnes of lost output.

Although production rebounded in 1981, the difficulties of years to come were foreshadowed in that year. Production costs at most operations were at or above 90 cents per pound⁴⁷ -- well above 1979 levels and putting

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Unless otherwise noted, all unit cost figures attributed to specific companies are derived from annual reports. They are cash operating costs before interest charges and byproduct credits. Metals contributing less than 30% of an operation's revenue are considered to be byproducts; where copper was only one of two or three principal products, production costs have been prorated among them according to revenue share. I am indebted to Robert W. Lauer, of the Department of Energy, Mines and Resources (Canada), for his collaboration in developing the program with which these figures were constructed, and for making cost series for a number of companies available to me.

the US near the upper end of the world cost curve' -- and the weakening price of copper (Figure 6.2.1a) was exacerbated by the beginning of the US dollar's phenomenal rise (Figure 6.2.1b).⁴⁸ By the end of the year, operating losses were widespread, cutbacks had been announced at a number of operations, and the nine major US companies had lost over US\$400 million.

As conditions worsened in 1982, the gap between price and operating costs (estimated at over \$1.40 at some mines) widened, and layoffs and closures continued at an accelerating rate. By September, the industry was operating at just over half of capacity, and at year-end, 14 of the 25 largest operations were closed. The nine major US companies lost over US\$1 billion that year, and the average number of mine workers dropped by one third from its 1981 level.

By contrast with the situation in most of the rest of the world, 1983 was a worse year for the US industry than 1982 had been. Significant cuts in operating costs were

⁴⁸ Ironically, just as the dollar's rise was getting under way in the spring of 1981, Metals Week printed an editorial which expressed concern that the Reagan administration's policy of non-interference in foreign exchange markets could hurt the US if the dollar were to weaken, but concluded by noting that "the indications from Administration officials are that they understand the necessity of pursuing economic policies that will buttress the dollar." "Free-floating Dollar?" Metals Week (4 May 1981).

Figure 6.2.1a

United States

Real Copper Price in Domestic Currency

(Index: 1980 Q1 = 100)

Figure 6.2.1b

United States

Real Effective Exchange Rates

(Indexes: 1980 Q1 = 100)

Note: Figures for latest periods are estimates.

made at most operations, but they were dwarfed by the effect of the rising dollar.⁴⁹ A number of mines which had opened in response to rising prices early in the year were soon forced to close again. By the end of the year, the nine largest companies had lost another US\$600 million, and the number of copper workers had dropped to half its 1981 level.

The attack on operating costs continued in 1984, with the threat of permanent closure generating union decertification drives at a number of companies. The industry's efforts to find political solutions to its distress also intensified: legislation increasing the United States' 1984 IMF contribution specified tightened terms for loans to mineral producers; and at the beginning of the year, eleven producers filed for relief from injurious imports under the Trade Act, seeking import quotas.⁵⁰

By 1985, it was evident that the impact of the depressed copper market and high dollar was going to leave a permanent mark on the US industry. Companies still

49 Duval Corp. managed to cut costs (in real terms) by 25% in 1983 as compared to 1982, but at 96 cents per pound, they were among the highest cost producers in the world.

50 The International Trade Commission ruled in favour of the application in August, but President Reagan rejected the decision, refusing to impose either tariffs or quotas.

operating had made enormous cuts in costs -- Phelps Dodge Corp., for example, lowered costs by one third in nominal terms (over half in real terms) from 1980-85 -- and were restricting their investments for the most part to inexpensive leaching operations. Several of the major names in the US industry a few years earlier (including the previous bugbear of Chilean nationalists, Anaconda) had, on the other hand, virtually disappeared.

Faced with continued inability to restore their competitive position by improvements in efficiency, American producers continued to push for political solutions to their difficulties. The US has reduced funding for development assistance related to copper, and in late 1985 a continuing resolution passed in Congress provided for negotiations with the five other big producers to limit exports to the United States to 1982 levels for five years (as of early 1986, President Reagan was refusing to act).

6.2.2 Canada

Like their US counterparts, Canadian producers started off the decade with good financial results and poor cost trends. Real Canadian dollar unit costs in 1980 were of the order of 10-20% over 1979 levels at many operations, and the appreciation of the real exchange rate against the US added a further 2% in US dollar terms. As the price of copper started to fall through 1980 and 1981, much of Canada's production was sheltered from the full effects of the decline by good byproduct revenues. (Copper price in Canadian dollars is shown in Figure 6.2.2a; Canada's real effective exchange rates are shown in Figure 6.2.2b.)

By 1982, however, byproduct prices had weakened considerably, with the big nickel producers and the western open pit operations (dependent on molybdenum and gold revenue) hardest hit. Closures and cutbacks accelerated through the spring. By June, the Kidd Creek operation, with its high zinc values, was the only Canadian producer running at capacity. In 1983 and 1984, Canadian producers made considerable progress in improving their efficiency, with average costs in 1983 below 1979 levels in most cases and 1984 seeing further reductions. The pause in the rise

Figure 6.2.2a

Canada

Real Copper Price in Domestic Currency

(Index: 1980 Q1 = 100)

Figure 6.2.2b

Canada

Real Effective Exchange Rates

(Indexes: 1980 Q1 = 100)

Note: Figures for latest periods are estimates.

of the North American currencies in early 1983 reinforced the slight recovery in price in Canadian dollar terms that year, reducing company losses.

Exchange rate developments had a further adverse effect on Canada's position through 1984, however, and Canadian dollar prices continued below those in all major producers except the US. By early 1985, the level of the Canadian dollar had become a major issue in the industry.⁵¹ Despite reductions in operating costs in the order of 40% from 1980 to 1985 in some cases, Canadian producers found that they had moved from the low to the high end of the world cost curve.

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A plea for a lower dollar was a principal feature in a Mining Association of Canada brief to the federal government that year (Mining Association of Canada, Economic Renewal and Canadian Mining [Toronto: 1985].)

6.2.3 Chile

In Chile also, good market conditions at the beginning of 1980 permitted relatively loose control over costs. Domestic currency costs rose by over 8% after inflation at Codelco's operations from 1979 to 1980. In addition, the effects of the fixed exchange rate and domestic inflation produced a real rise in US dollar terms of about 23%. Chile's phenomenally favourable resource endowment, however, meant that production costs in 1980 were only 57 cents per pound, well below those of virtually all rivals.

The weaker market of 1981 (see Figure 6.2.3a) was accompanied by efforts at rationalization at Codelco, resulting in some decrease in costs. These were largely offset by the continued appreciation of the real exchange rate (Figure 6.2.3b), however, and only the giant Chuquibambilla mine operated at a profit during the year. By summer, the private miners' association, Sonami, estimated that 50,000 tonnes of capacity at small and medium mines were closed because of the weak market. Chilean output suffered further in 1981 from a two month strike at Codelco's El Teniente mine, the worst strike in Chile since 1968.

Figure 6.2.3a

Chile

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Real Copper Price in Domestic Currency

(Index: 1980 Q1 = 100)

Figure 6.2.3b

Chile

Real Effective Exchange Rates

(Indexes: 1980 Q1 = 100)

Note: Figures for latest periods are estimates.

These developments were reflected in a pronounced widening of Chile's trade and current account deficits (from US\$0.8 billion and US\$2 billion respectively in 1980 to US\$2.7 billion and US\$4.7 billion in 1981), exacerbated by the effects of high interest rates on the burden of debt service. By the first half of 1982, interest payments exceeded 35% of export earnings, and Chile was forced to abandon its experiment with a fixed exchange rate, devaluing the peso in June.

Late in 1982, expansions at El Teniente and Chuquibambilla were completed, and through the end of the year and into 1983, further projects were initiated both at state-owned and at private mines. Codelco borrowed US\$305 million from a consortium of private banks in December of 1982, and by December of 1983 had arranged for a US\$268 million loan from the Inter-American Development Bank, as part of a US\$2 billion expansion plan over five years. While retrenching elsewhere, foreign investors looked at Chile with renewed enthusiasm: in 1983, Exxon commenced expansions at both ~~its~~ Disputada mines.

Through 1984 and 1985, Codelco made little progress in reducing its costs in domestic currency terms, but the effect of continued exchange rate depreciation was to lower its costs to 36 cents in 1984 and 34 cents in 1985, unques-

tionably the lowest in the western world.⁵² Expansions and modernizations throughout the Chilean industry have continued, boosting production to new records, despite heavy storm damage at Codelco operations in 1984 and earthquake-related disruptions in 1985. Chile has also continued to attract international finance for copper production from both public and private sources -- in 1985, the World Bank provided a US\$100 million loan for the small mining sector, and Canada's Rio Algom obtained US\$240 million from a variety of sources for its Cerro Colorado project.

6.2.4 Peru

Peru's copper industry has faced a number of problems during the 1980s in addition to the depressed market for its product -- in particular, chronic labour unrest and deteriorating monetary management. At the beginning of the decade, production costs at SPCC were, at about 63 cents, relatively low. In 1981 and 1982, despite production lost to strikes and natural disasters, the company managed to adjust to declining prices (Figure 6.2.4a) by lowering its costs in inflation-adjusted Peruvian currency terms by a total of almost 10% in the two years. Because of the gradual appreciation of the exchange rate relative to other producers (Figure 6.2.4b), however, Peru's industry began to find itself losing ground against its Latin American and African rivals.

Like Chile, Peru found itself under increasing balance of payments pressure in these years, as the trade and current account balances shifted from surpluses in 1980 to deficits of about US\$500 million and US\$1.7 billion respectively in each of the next two years. Debt service alone grew to exceed 20% of export earnings by the second half of 1982. These pressures led to a sharp decline in the value of the currency in early 1983, but the advantage

Figure 6.2.4a

Figure 6.2.4b

Note: Figures for latest periods are estimates

obtained by the devaluation was more than dissipated by inflation, which exceeded 100% that year. SPCC's output was also cut by an unprecedented figure of some 45,000 tonnes in 1983 as a result of strikes, and unit costs rose almost 12% after inflation.

In 1984 and 1985 the management of the Peruvian exchange rate continued to be complicated by inflation, which exceeded 160% in the latter year, while costs at SPCC rose even faster than other prices in the economy. Average cost at SPCC was about 64 cents in 1985, virtually unchanged (in nominal terms) from 5 years earlier; at Phelps Dodge in the US, by contrast, costs had been cut by one third, despite a massive exchange rate disadvantage. Even with the coming on stream of the Tintaya project in mid-1985, Peru's market share was well below its 1979 level that year. The pronounced appreciation of the real effective exchange rate in late 1985 and early 1986 suggests that Peru's competitive position has continued to erode.

6.2.5 Zaire

Developments in the copper industries of the two African producers during the 1980s provide several contrasts. Zaire's 1980 production was still down slightly in the aftermath of the 1978 invasion, which made it difficult for Gecamines to recruit skilled expatriates. The opening of two new mines and a rise in production at the Sodimiza operations boosted output in 1981.

As the copper market deteriorated in 1981 and 1982, the Zairean industry was shielded to some extent by the simultaneous lifting of a heavy export tax -- which had amounted to some 48 cents a pound in 1980 -- and the devaluation of the zaire in mid-1981 (see Figure 6.2.5b). Through 1982, however, high inflation and a collapse in the price of cobalt produced heavy stresses on the Zairean economy. The current account, which had shown a US\$146 million surplus in 1979, reached a deficit of US\$433 million in 1982. Despite US\$38 million in aid from the EEC, Zaire's foreign exchange reserves had dwindled to a wafer-thin US\$23 million by the second quarter of 1983.

In that year, Zaire began the implementation of a US\$428 million IMF stabilization program, a centrepiece

Figure 6.2.5a

Figure 6.2.5b

Note: Figures for latest periods are estimates.

of which was a massive devaluation of the zaire from its overvalued level of the beginning of the decade. This measure, which was followed by the adoption of a floating exchange rate in the summer of 1984, produced the spectacular rise in the zaire price of copper evident in Figure 6.2.5a.

A number of other reforms have followed, with the abolition of the state-run copper marketing firm, Sozacom, and a badly-needed restructuring of Gecamines (the second stage of an EEC SYSMIN loan was held up in 1985 when Gecamines could not account for US\$150 million in uninvoiced sales from 1982-84). The willingness of foreign donors to contribute US\$300 million to a planned US\$750 million modernization program testifies to the improved financial state of the Zairean industry, as does the rebound in Zaire's copper production in 1985.

6.2.6 Zambia

If the story of Zaire's copper industry during the 1980s is one of resilience amid improving macroeconomic management, that of Zambia is one of decline amid deterioration. (The profile of copper prices in deflated kwachas is shown in Figure 6.2.6a; that of the real effective exchange rates in 6.2.6b.) At the beginning of the decade, Zambian copper mines were at the upper end of the world cost curve, with cash operating costs around 90 cents. 1981 production costs were slightly higher in terms of deflated kwachas -- in contrast to the situation among most other producers, where real domestic currency costs fell in line with the deteriorating market -- but this rise was more than offset by a weaker exchange rate. Output suffered from both politically and economically motivated strikes over the year.

A deterioration in Zambia's current account in 1981 (a small surplus in 1979 had changed to a deficit of almost US\$750 million) provided impetus for agreement by the government to a US\$850 million IMF stabilization program over three years, but disbursement was halted in the summer of 1982 when conditions concerning devaluation and the closure of some unprofitable mines were not met. While the

Figure 6.2.6a

Figure 6.2.6b

Note: Figures for latest periods are estimates.

kwacha weakened against the US dollar during 1982, it was allowed to strengthen against the currencies of most producers, and the fall in kwacha copper prices was relatively steep. Despite considerable success in reducing costs, and a US\$54 million EEC loan, the financial position of Zambia's mines deteriorated significantly.

1983 saw a temporary improvement. Strengthening copper prices and a weaker currency helped Zambia Consolidated Copper Mines (ZCCM), the state-controlled company formed in 1982 as part of a rationalization effort, show a profit in the first three quarters, and Zambia's trade balance returned to the black, after two years of deficits. Lack of access to the foreign exchange generated by its exports hampered ZCCM in its efforts to maintain output, however, and in early 1984, lack of spare parts and fuel had idled three quarters of the company's fleet of trucks. Average cash operating costs in kwacha terms rose by over 10% in 1984.

It is likely that the drop in Zambian production in 1985 reflects in part the beginning of an extensive program, financed largely by the World Bank (\$75 million) and the European Development Bank (\$70 million) to rationalize the industry, and close uncompetitive capacity.. At the end of 1985, further international assistance was forthcoming, in the form of an ECU 28 million loan from the EEC. The

sharp devaluation of the kwacha in the fourth quarter brought about a steep rise in Zambian copper price, but the acceleration of inflation in the year caused this advantage to be quickly eroded.

6.2.7 All Producers

A number of the western world's smaller producers, less dependent on revenue from copper exports than Chile, Zaire and Zambia, also suffered from relatively strong exchange rates during this period. The Philippines (from 1981 on) and Australia (1984) are producers whose reductions in output appear to be related to comparative exchange rate strength. The most dramatic examples of exchange rate-related shifts in market share are evident in the cases of the two biggest producers, however, with the decisive emergence of Chile over the United States as the western world's dominant source of copper in the years since 1982.

To close this review of the 1980-85 period, Figure 6.2.7 illustrates the course of the weighted average of all copper producer real exchange rates against the corresponding consuming country basket since 1980. In 1981 and 1982, this measure was relatively strong, as the producers maintained exchange rates at levels inconsistent with their deteriorating external balances. As the depression in the copper market persisted, however, the weakened purchasing power of producers came to be reflected in their exchange rates, and the aggregate measure reveals a decline

Figure 6.2.7

Producers

Real Effective Exchange Rate against Consumers

(Index: 1980 Q1 = 100)

Note: Figures for latest periods are estimates.

that lasted up until the end of 1985. After the initial delay, the decline in producers' exchange rates continued even as world stocks of copper were drawn down in 1984 and 1985. It is interesting to speculate about the extent to which this decline of production costs, measured in consuming country currencies, is responsible for the continuation of low consuming-country-currency copper prices through those last two years.

6.3 Summary

The possibility that exchange rate changes can have effects on quantities supplied and traded in commodity markets is widely acknowledged, and exchange rates have frequently been cited in analyses of commodity market behaviour. In recent years, the importance of exchange rate movements to the world copper industry has been highlighted by many market analysts, largely because of the simultaneous weakness of many producing country currencies and the extreme hardship experienced by the North American copper mining industry.

There are good reasons for supposing that exchange rate changes will affect a producer's ability and willingness to continue or raise production. Real exchange rate movements -- that is, those that are not offset by changes in domestic price/cost levels -- will affect the margin between the price received by a national industry for its product, and the costs incurred in producing it. As a consequence, changes in the exchange rates of copper producers with respect to each other can have important effects on competitive position, and may change the shape of the supply curve.

The effects of exchange rate and domestic price level changes on competitiveness in a single market can be measured by a specialized real effective exchange rate index, and such an index can be used in econometric tests to determine whether or not these changes appear to have had an effect on the physical market. Given the multitude of forces that affect the output of a commodity such as copper, it would be unrealistic to expect a simple statistical test to give conclusive answers. Nevertheless, the results of the tests on market share presented in this paper lend support to the hypothesis that changes in competitive position, as measured by such an index, are correlated with changes in relative volumes of copper output. In the cases of the US and Chile particularly, the 1980-85 period offers a dramatic example of this relationship -- the strong dollar of recent years has coincided with staggering losses and widespread closures in the US, while the Chilean industry, aided by a declining peso, has expanded vigorously.

The choices of cost deflator and weighting system used in the indexes in this paper were dictated in part by a desire to use measures that would be familiar and easily accessible to those interested in markets other than that for copper. This approach doubtless has costs: GDP deflators are far from exact indicators of changes in mining costs; government supports and impediments to copper

mining are ubiquitous and subject to change; and price differentials in regional markets may vary over time. Nevertheless, the results are not discouraging.

It is likely that exchange rate changes have similar or more dramatic effects on the supply of other commodities, such as annual crops. Although problems like those encountered with copper may complicate the study of this phenomenon in other markets, similar investigations should prove fruitful. More sophisticated input cost indexes are available in a number of areas. And different weighting systems will be appropriate to other markets.

In a number of respects, the outlook for the world economy is more positive now than it has been for well over a decade. Even under the most optimistic projections, however, markets for both currencies and primary commodities are likely to continue to be subject to sharp swings and periods of pronounced imbalance. A better understanding of the ways in which these markets interact can be expected to produce benefits for producers, consumers and traders alike. The example of copper suggests that, in the field of exchange rates and primary commodity trade, further research can be expected to prove both interesting and profitable.

Appendix: The Development of a Real Effective Exchange Rate Index

This appendix describes the theory and method behind the construction of the real effective exchange rate indexes used in this paper. The discussion involves a brief introduction to the use of index numbers and a review of real (that is, inflation adjusted) and effective (or weighted) measures, as well as the combination of the two. Finally, it explains the use of a harmonic mean in the averaging process.

A.1 The Use of Index Numbers

The use of index numbers is crucial in the development of any type of real effective exchange rate. An index number is a ratio of two values, expressing the difference between them as a percentage. While these numbers have many applications, the most common involves the construction of time series showing changes in an item relative to a base period, which is usually set at 100.

A principal use of time series index numbers is in measuring price changes. An index may be used to show changes in one item alone -- such as a pound of copper in US dollars, or the Chilean peso in US dollars -- or it may be constructed to show changes in a number of prices, as is the case with national consumer price indexes (CPIs) and gross domestic product (GDP) and gross national product (GNP) deflators. The use of index numbers facilitates comparison of measurements made in different currencies, or at different times.

A.2 Nominal Measures

The basic measure of any price, whether that of a currency or a commodity, is the nominal one -- the ratio of a given amount (e.g., one pound) to a given currency. The currency most frequently used in exchange rate and commodity price quotations is the US dollar, and indexes can be easily constructed using US dollar quotations.

Table A.2.1 Nominal Exchange Rates: USA, Canada and Chile

	US\$ per NCU			Indexes: 1980 = 100		
	USA	Canada	Chile	USA	Canada	Chile
1980	1.00	0.85	0.026	100.0	100.0	100.0
1981	1.00	0.83	0.026	100.0	97.6	100.0
1982	1.00	0.81	0.020	100.0	95.3	76.6
1983	1.00	0.81	0.013	100.0	95.3	49.6
1984	1.00	0.77	0.010	100.0	90.6	39.5
1985	1.00	0.73	0.006	100.0	86.2	24.3

Source: IMF.

By way of illustration, Table A.2.1 shows the exchange rates of the United States, Canada and Chile against the US dollar over the 1980-84 period, both in terms of US dollars per national currency unit (NCU), and as an index, with 1980 set at 100.⁵³ The index numbers facilitate

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1980 is used as the base year throughout this paper. The choice of a base year implies, in many instances, some sort of judgement about equilibrium or normalcy. As will be seen later, however, no such judgement is necessary in this context. 1980 is currently the base year for IMF measurements, and is used here purely for convenience.

comparison of the relative courses of the Canadian and Chilean currencies against the US dollar over the period.

Table A.2.2 Nominal Copper Prices: USA, Canada and Chile

	NCUs per Pound			Indexes: 1980 = 100		
	USA	Canada	Chile	USA	Canada	Chile
1980	0.99	1.16	38.7	100.0	100.0	100.0
1981	0.79	0.95	30.9	79.8	81.7	79.8
1982	0.67	0.83	34.2	67.7	71.0	88.4
1983	0.72	0.89	56.7	72.7	76.3	146.6
1984	0.62	0.81	61.4	62.6	69.1	158.7
1985	0.62	0.85	99.9	62.6	72.7	258.2

Source: IMF.

Table A.2.2 shows a similar presentation of the price of a pound of copper on the LME over the period. As a consequence of the exchange rate movements shown in the preceding table, the course of copper prices in each country is not the same.⁵⁴

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The remainder of this appendix will be clearer if it is noted that the presentation of domestic prices abandons (temporarily) the frame of reference of an outside observer. It should be noted that from the perspective of an observer in a fourth country, prices in the three would be the same in all periods.

A.3 Real Measures

The principle of adjusting nominal prices to reflect the declining purchasing power of a currency over time as a result of general price inflation is a familiar one. The adjusted measure can be displayed in the currency units of a particular period, such as 1980 US dollars, or in index form. Price changes in such a series are often called "real", to distinguish them from changes that merely reflect changes in general price levels. The most broadly based measures of general price inflation are the GDP and GNP deflators. Table A.3.1 shows GDP/GNP deflators for the USA, Canada and Chile.

Table A.3.1 GDP/GNP Deflators: USA, Canada and Chile
(Indexes: 1980 = 100)

	USA	Canada	Chile
1980	100.0	100.0	100.0
1981	109.6	110.6	112.2
1982	116.2	122.0	127.1
1983	120.7	128.7	160.9
1984	125.2	132.5	191.7
1985	130.3	136.3	244.3

Source: IMF.

Deflating the nominal copper prices in Table A.2.2 by these deflators gives real (1980 currency units) price series, for which indexes can also be constructed. These real copper prices are shown in Table A.3.2. Movements in these series signify that changes in the price of copper in each country have not simply been in line with the move-

ments in that country's general price level, and that the relationship between the price of copper and other prices in the economy -- presumably including the costs of producing copper -- has changed.⁵⁵

Table A.3.2 Real Copper Prices: USA, Canada and Chile

	1980 NCUs per Pound			Indexes: 1980 = 100		
	USA	Canada	Chile	USA	Canada	Chile
1980	0.99	1.16	38.7	100.0	100.0	100.0
1981	0.72	0.86	27.5	72.8	73.9	71.1
1982	0.58	0.68	26.9	58.2	58.2	69.5
1983	0.60	0.69	35.2	60.3	59.3	91.1
1984	0.50	0.61	32.0	50.0	52.2	82.8
1985	0.48	0.62	40.9	48.1	53.3	105.7

A similar process can be used to produce indexes of real exchange rates against the US dollar. The use of the term "real" with reference to exchange rates is similar to its use with reference to copper prices. It signifies that changes in the national currency unit/US dollar exchange

55 Once again, the shift from the point of view of an outside observer to the point of view of a domestic observer is disorienting. It is all the more disorienting in this case, however, because of the use of "real" -- or inflation-adjusted -- prices. It bears repeating that from an outsider's point of view, the price of copper in the three countries is always the same, and it is the inflationary trends in the three countries (filtered through their various exchange rates against the observer's currency) that are different.

rate have not simply been in line with changes in general price levels or, in other words, that changes in the external value of the currency have not exactly mirrored changes in its internal value.⁵⁶

In this case, however, conceptual complications arise because the unit being used as a measure of value (the US dollar) is not the only item subject to changes in purchasing power because of inflation or deflation. The unit being valued -- itself a currency -- is also subject to inflation. The real exchange rate measure therefore requires an adjustment for

⁵⁶ An exchange rate change that acted to offset exactly differentials in inflation rates, on the other hand, is often termed a monetary, rather than a real, phenomenon. This distinction is central to the theory of purchasing power parity (or, as a similar formulation is called, producing power parity).

Briefly stated, the theory of purchasing (producing) power parity postulates that different changes in the general levels of prices (costs) in two countries will cause their exchange rates to move so that the relative price (cost) of purchasing (producing) a similar range of goods in either country, at the current rate of exchange, will remain the same. If a change does occur, some real -- rather than purely monetary -- factor would appear to be at work.

The theory of purchasing power parity as a critical factor in determining exchange rates was first set out by Gustav Cassel in the 1910s and 1920s. He was the first to use the phrase and the first to test the theory using averages of prices. The idea of producing power parity has enjoyed equal popularity since the 1930s, and assumed a modern form with the work of Sven Brismar, who proposed a theory based on unit factor costs. See L.H. Officer, "The Purchasing-Power-Parity Theory of Exchange Rates: A Review Article," IMF Staff Papers 23:1 (March 1976).

general price level changes in both currencies.⁵⁷ Table A.3.3 gives the results of this process for the same three countries.

Table A.3.3 Real Exchange Rates: USA, Canada and Chile
(Indexes: 1980 = 100)

	USA	Canada	Chile
1980	100.0	100.0	100.0
1981	100.0	98.5	102.4
1982	100.0	100.1	83.7
1983	100.0	101.6	66.1
1984	100.0	95.9	60.4
1985	100.0	90.1	45.5

The movements in the series for Canada indicate that, at least until 1984-85, changes in Canada's nominal exchange rate against the US dollar have roughly offset differences between Canadian and US inflation. The Chilean

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The formula for a real exchange rate is:

$$RER_x = NER_x / \frac{DEFL_x}{DEFL_{US}} \cdot 100$$

Where RER_x = the real exchange rate of country x against the US dollar;
 NER_x = an index of the nominal exchange rate of country x against the US dollar;
 $DEFL_x$ = an index of prices/costs in country x; and
 $DEFL_{US}$ = an index of prices/costs in the US.

It should be noted that these indexes are mathematically equivalent to measures of relative price changes adjusted for exchange rate movements. In its most recent World Economic Outlook, the IMF adopted the terminology of adjusted relative prices, perhaps to ease conceptual confusion (pp. 34-35), although the real exchange rate terminology is also used in the report (pp. 42-43). See Maciejewski 1983, especially p. 492.

real exchange rate series, on the other hand, shows that the decline in the US dollar value of the peso has been greater than inflation differentials would indicate.

A.4 Effective Measures

There are many situations in which an exchange rate measured against the US dollar alone may not be a satisfactory measure. To continue this example, the movements of the currencies of each of the US, Canada and Chile against the other two may be of interest (in the indexes used in this paper, the exchange rate measure used is that of each country against the eleven most significant of its copper-producing competitors). Recent years have seen the development of a variety of new exchange rate measures, designed to reflect the movements of a country's currency against those of trading partners or competitors. This type of measure -- the ratio of one country's currency to a weighted average of those of the other relevant countries -- is often called an "effective" exchange rate, to indicate the wider significance of the changes it captures.⁵⁸

The choice of weights used in the construction of an effective exchange rate depends on the market conditions of

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Because of the various weights and units involved in its calculation, an effective exchange rate expressed in terms of currency units would be somewhat obscure, and an index must be used.

the commodity or sector in question.⁵⁹ In general, the less ambitious the intent of the index, the narrower the sector, and the more undifferentiated the product, the simpler a weighting system can be. When the intent is to show direction of change, and when the product (like copper) is a homogeneous commodity traded in a well-integrated market, world production/consumption or export/import shares would suffice.⁶⁰

Table A.4.1 Three-Way Nominal Effective Exchange Rates:
USA, Canada and Chile
(Indexes: 1980 = 100)

	USA	Canada	Chile
1980	100.0	100.0	100.0
1981	100.8	98.4	100.8
1982	111.9	106.5	85.6
1983	135.5	129.1	67.2
1984	154.6	140.1	61.0
1985	209.5	180.5	50.8

For the purpose of illustration, a calculation of this type for the US, Canada and Chile is shown in Table A.4.1.

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Many effective indexes are published, such as those of the IMF, weighted according to its Multilateral Exchange Rate Model (MERM), Morgan Guarantee (15 countries, using averages of import- and export-weighted indexes), the US Federal Reserve (11 countries, weighted by shares of world-wide trade), and the OECD (23 countries plus rest of world, weighted by a method similar to the MERM). Indexes for individual countries only are also published by various central banks and government agencies. See R.R. Rhomberg, "Indices of Effective Exchange Rates," IMF Staff Papers 23:1 (March 1976), and David L. Deephouse, "Using a Trade-Weighted Currency Index," Federal Reserve Bank of Atlanta Economic Review (June/July 1985).

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Feltenstein, Goldstein and Schadler use weights based on import and export shares in their elaboration of a multilateral exchange rate model for commodity exporters. They mention, however, that in the case of copper, production and consumption shares could be used. See A. Feltenstein et al., "A Multilateral Exchange Rate Model for Primary Producing Countries," (September 1979).

The "three-way effective" rates shown represent the ratio of each country's nominal exchange rate index to an equally weighted harmonic average of the nominal indexes of all three.⁶¹ This is the sort of measure that could be used to investigate an exchange rate-related problem involving these three countries only.

⁶¹ The reason for using a harmonic mean is explained in Section A.6.

A.5 Real Effective Measures

An exchange rate measure that incorporates both adjustments for inflation and a weighting system is known as a real, effective exchange rate. As a final step in the illustrative process, Table A.5.i shows three-way real effective exchange rates of the USA, Canada and Chile against each other. These indexes were produced in a fashion analogous to that for the nominal effective rates in the above table, except that real exchange rates, rather than nominal ones, were used in their construction.

Table A.5.1 Three-Way Real Effective Exchange Rates:
USA, Canada and Chile
(Indexes: 1980 = 100)

	USA	Canada	Chile
1980	100.0	100.0	100.0
1981	79.7	98.3	102.1
1982	106.5	106.5	89.1
1983	116.5	118.4	77.1
1984	123.3	118.2	74.5
1985	143.6	129.4	65.3

Depending on the area of inquiry, a wide variety of price deflators and weighting systems can be used in such indexes. At its most ambitious, a real effective exchange rate can be designed to incorporate relative movements in exchange rates and price levels in a country and all its trading partners and competitors, so as to produce a single

measure indicative of the effects of changes in all these factors on the first country's balance of payments. This is the intent of the IMF's MEKM indexes.⁶²

As was indicated earlier, a narrower focus of study will likely involve a simpler choice. For most LDCs, only a few, if any, price deflators are available -- generally the consumer price index (CPI) and the GDP or GNP deflator.⁶³ And when the intent, as here, is to measure direction of competitiveness in a well integrated market for a homogeneous commodity, a production-based weighting system will suffice.⁶⁴

The indexes presented in this paper make use of GDP deflators for measures of price/cost changes, except in the

⁶² The real effective exchange rate indexes produced by the IMF are producing-power oriented, using unit labour costs. In its 1985 World Economic Outlook, the IMF also calls these series "Relative Prices of Manufactures Adjusted for Exchange Rate Changes" (IMF, 1985, pp. 34-35).

⁶³ The objection may be raised that these measures assume that CPIs and GDP/GNP deflators are good indicators of costs of copper production, which may not be true. This point is a valid one. Better series are not readily available for all copper producers, however, and in the interest of consistency, it seems desirable to use the same measure for each. Various measures of national inflation are, in any case, highly correlated.

⁶⁴ An index of this sort was recently used by Jeffrey Rosenweig to investigate the impact of the value of the US dollar on the US travel deficit. His index consisted of a geometric average of the CPI-adjusted exchange rate of the US dollar against the US' ten principal travel partners. See Rosenweig, 1985.

cases of Belgium and Canada, for which GNP deflators were used, and Yugoslavia, for which the gross material product deflator was the only available measure. In a number of cases, it was necessary to estimate 1985 figures for the GDP deflator from CPIs.

The weights used in the indexes are: for producers, share of mine production of copper among the twelve largest producers from 1961 to 1985; and for consumers, share of refined copper consumption among the ten largest consumers over the same period. Table A.5.2 gives the weights allocated each country.

Table A.5.2 Weighting System for Real Effective Exchange Rates in the Copper Market

Producer	Weight (%)	Consumer	Weight (%)
Australia	3.7	Australia	2.1
Canada	12.7	Belgium	3.7
Chile	17.6	Brazil	2.4
Mexico	2.1	Canada	4.1
Papua New Guinea	2.0	France	6.7
Peru	5.2	West Germany	12.9
Philippines	3.8	Italy	5.5
RSA & Namibia	3.9	Japan	17.2
United States	25.9	United Kingdom	9.5
Yugoslavia	2.0	United States	35.9
Zaire	8.3		
Zambia	12.9		

This group includes all countries accounting for more than 2% of western world mine production and refined consumption since 1961, and represents 92% and 85% respectively of the western world's production and consumption over the period.

A.6 The Use of a Harmonic Mean

The harmonic mean is the least familiar of the three available averaging formulas (the other two being the arithmetic and the geometric). Its formula is as follows:

$$\sum \frac{WT_1}{RER_1}$$

Where WT_1 = the weight given to country 1; and
 RER_1 = the real exchange rate of country 1.

Not only is the harmonic mean somewhat obscure, its use in index numbers has been justifiably criticized on a number of grounds, among which are its downward bias, and the non-reversibility of time series generated with it.⁶⁵ In the production of a series measuring changes in cost competitiveness, however, the harmonic average has merits which can be demonstrated by the following highly simplified example.

Imagine a commodity market in which virtually all productive capacity -- say 200 units -- is located in two

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See Irving Fisher, The Making of Index Numbers (Boston: 1927).

countries, A and B. Each of these countries contains 100 individual producers capable of producing one unit apiece, and short-term variable production costs (which are entirely domestically determined) among the producers in each country range uniformly from 1 to 100.

In an initial period, the supply curve in this market can be represented as in Figure A.6a. The vertical axis represents costs (measured, as before, in the currency of a third country, in this case Country C); the horizontal axis shows production per unit of time. Quantity produced is a function of price and the respective costs and capacities of the industries in the two countries. In the base period, cost indexes for both A and B,

Figure A.6a

Position of Producer in Country C on Supply Curve
before Cost Changes in Competitors

as calculated with a real exchange rate index against the currency of country C, are 100. The formula for quantity supplied looks like this:

$$Q = \frac{P}{\text{COST}_A} \cdot \text{CAP}_A + \frac{P}{\text{COST}_B} \cdot \text{CAP}_B$$

$$= P \cdot \left(\frac{\text{CAP}_A}{\text{COST}_A} + \frac{\text{CAP}_B}{\text{COST}_B} \right)$$

Where Q = quantity produced;

P = price measured in Country C's currency;

COST_x = the cost index (real exchange rate against Country C) of Country x;

CAP_x = the capacity of Country x;

and where the quantity supplied by each of A and B individually cannot exceed 100.

Imagine further a single producer, of negligible weight, in Country C, whose costs are 50. The cost-competitiveness ranking of this producer (i.e., his position with respect to the other producers in the market, or his position on the quantity axis) can be ascertained from this same formula, by determining the quantity that will be produced when price is equal to his cost of production. In other words, the formula for the cost ranking of the country C producer is as shown on the following page.

$$\begin{aligned}
 \text{RANK}_C &= \frac{\text{COST}_C}{\text{COST}_A} \cdot \text{CAP}_A + \frac{\text{COST}_C}{\text{COST}_B} \cdot \text{CAP}_B \\
 &= \text{COST}_C \cdot \left(\frac{\text{CAP}_A}{\text{COST}_A} + \frac{\text{CAP}_B}{\text{COST}_B} \right)
 \end{aligned}$$

Where RANK_C = Country C's position on the quantity axis; and all other variables are defined as above.

The transformation of this formula to:

$$\text{RANK}_C = \text{COST}_C / \frac{1}{\frac{\text{CAP}_A}{\text{COST}_A} + \frac{\text{CAP}_B}{\text{COST}_B}}$$

produces a denominator analogous to the formula for the harmonic mean -- the weights of the various producers being equal to their respective capacities, expressed as a proportion of the total capacity in the market.

To illustrate the superiority of this measure in practice, assume that -- in a subsequent period -- real exchange rate movements occur such that the costs (measured in Country C's currency) of producers in Country A drop by half, while costs in Country B double. Country A's real exchange rate index now stands at 50; that of Country B at 200. The new supply curve is represented in Figure A.6b. The producer in Country C, whose costs are unchanged, can be seen to occupy a position of 125 on the quantity axis --

Figure A.6b

Position of Producer in Country C on Supply Curve
after Cost Changes in Competitors

that is, its cost competitiveness ranking has changed from 100 to 125.

The harmonic averaging technique yields the same result. The Country C producer's new rank can be calculated as follows:

$$\begin{aligned}
 \text{NEW}_C &= \text{OLD}_C / \left(\frac{\text{WT}_A}{\left(\frac{\text{NEW}_A}{\text{OLD}_A} \right)} + \frac{\text{WT}_B}{\left(\frac{\text{NEW}_B}{\text{OLD}_B} \right)} \right) \\
 &= 100 / \left(\frac{0.5}{0.5} + \frac{0.5}{2.0} \right) \\
 &= 125
 \end{aligned}$$

Where NEW_x = the new cost index of country x ;
 OLD_x = the old cost index of country x ; and
 WT_x = the weight of country x .

By contrast, an arithmetic average yields:

$$\begin{aligned} NEW_C &= OLD_C / \left(WT_A \cdot \frac{NEW_A}{OLD_A} + WT_B \cdot \frac{NEW_B}{OLD_B} \right) \\ &= 100 / (0.5 \cdot 0.5 + 0.5 \cdot 2.0) \\ &= 80 \end{aligned}$$

while a geometric average yields:

$$\begin{aligned} NEW_C &= OLD_C / \text{Antilog} \left(WT_A \cdot \log \frac{NEW_A}{OLD_A} + WT_B \cdot \log \frac{NEW_B}{OLD_B} \right) \\ &= 100 / \left(\text{Antilog } 0.5 \cdot \log(0.5) + 0.5 \cdot \log(2.0) \right) \\ &= 100.66 \end{aligned}$$

It should be noted that in situations where the costs of producers in Country A and Country B are not uniformly distributed, or where price/cost levels in Country C have also changed, this process may not produce results that are as accurate as in this example. The harmonic mean is, nevertheless, superior to the alternatives in this area.

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The difference in indicated direction of change that can result from different averaging methods is a striking example of the importance of choosing an appropriate method in constructing an index of this sort. On the varying conclusions that can be drawn from tests with very similar indexes, see Michael T. Belongia, "Estimating Exchange Rate Effects on Exports: A Cautionary Note," Federal Reserve Bank of St. Louis Review (January 1986).

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