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The Impact of Copper in the Chilean Economy

The purpose of this chapter is to describe the interrelationship between the copper sector and the rest of the economy in Chile and to analyze the possible impact on the economy of changes taking place in the copper sector. The chapter thus rests on a macroeconometric model that is both descriptive and useful for simulating the impact of fluctuations in the copper sector. The study first centers on exogenous price changes and later on changes in three policy variables: tax rates, exchange rates, and investment. Although the empirical analysis is somewhat dated, the methodology employed should be of help in the design of government policies relating to the copper sector.

Chile is endowed with an important portion of the world's reserves of copper. The main part of its production is extracted from three large mines; exports from these mines fluctuated between 38 percent and 66 percent of the total exports of the economy during the period 1956–1968. In this same period government receipts from these mines fluctuated between 6.3 percent and 17.1 percent of total government receipts. The three mines (Chuquicamata, El Salvador, and El Teniente) were owned by foreign interests during this period. Both because of their relative importance in total Chilean copper production and because of the great differences in technology and legal treatment as compared with the smaller mines, policy analysis is focused on these

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three mines. According to Chilean law, they belonged to what was called the "Gran Mineria del Cobre" (copper large-scale mining).

In the next section, the model is presented and briefly discussed. It is then solved numerically, and the solution is compared with the actual values for the period 1956–1968. In order to gain insight into the functioning of the model, some simulations of changes in the noncopper sector are presented. The third section is devoted to a simulation of possible impacts of an exogenous copper price change. These results depend largely on how the Chilean government would react to such changes. Finally, the fourth section presents simulations of the impact of changes in policy variables related to the copper sector. Here the results depend not only on the government's reaction, but also on the reaction of the copper companies through their investment policies.

THE MODEL

General Features

The present study has called for a model that can describe in a simplified way the impact of the copper sector on the economy as well as can evaluate the behavior of what are considered the most important variables in that sector. They are (a) the prices of copper, (b) investment in copper, (c) tax rates on the copper companies, and (d) discriminatory exchange rates in the copper sector. It would have been preferable to build a detailed model of the copper sector and to link it with an existing macroeconometric model of Chile.[1] While such an exercise has been performed in Chapter 7, the preliminary nature of this study required a small and more manageable two-sector model.[2]

The model finally adopted possesses the following characteristics:

1. The economy is divided into two sectors. One sector comprises large-scale copper mining, defined by Chilean law as the "Gran Minería del Cobre." The other sector features the rest of the economy.
2. The price of copper is taken as exogenous. The model is designed to simulate the effect of different sets of copper prices. While changes in Chilean supply are assumed not to affect the world price of copper, one can also interpret the simulated prices as those prevailing "after" the reaction of Chilean supply has taken place. A more complete model would endogenize copper prices, linking the model with a model of the world copper market.
3. The noncopper sector is demand-based. Except for the fact that it is linked to the copper sector and possesses a few other special fea-

tures, it basically works as a Keynesian model. The corresponding copper sector is supply-based. A major simplification adopted has been the leaving out of sales of copper to the national manufacturing industry, both because such sales are minimal and because descriptive data are lacking. The only link from the noncopper to the copper sector is through the exchange rate.

4. From the point of view of foreign trade, the copper sector produces a net inflow of foreign exchange and the noncopper sector a net outflow. These flows are summarized with one equation for each sector; all consumers are assumed to belong in the noncopper sector.
5. The change in money supply is related to the government deficit and the change in foreign reserves, two variables that depend a great deal on copper. The change in money supply, in turn, affects the level of prices.
6. To simplify the model, only one price deflator is employed.

The model consists of twenty-eight equations; eleven are stochastic, and seventeen are definitions. Two of the definitions contain a parameter imposed with the help of extraneous information. Owing to limitations in the data, the period of estimation varies in different equations, the longest being 1950–1971. The method of estimation used is ordinary least squares.[3] For the sake of comparison, we also estimated the consumption function by two stage-least squares; the results are presented in note 4.

Figure 8–1 describes the flows between the sectors of the model. One can see how consumption, investment, government, and the foreign sector converge to determine income. The copper sector enters through government and foreign trade. Both total investment and investment in copper are exogenous. Investment in copper affects production capacity in some of the simulations. Production capacity, together with the world price of copper, determine the production of copper. The definitions of the variables and the data sources are presented in the chapter Appendix.

The Equations

In presenting the equations of the model, a detailed discussion of the underlying hypotheses has been omitted. In parentheses next to each heading are presented the period of estimation and the $\bar{R}^2$. In parentheses below the coefficients of the stochastic equations are the values of the t-statistic. The Durbin-Watson values do not suggest autocorrelation.

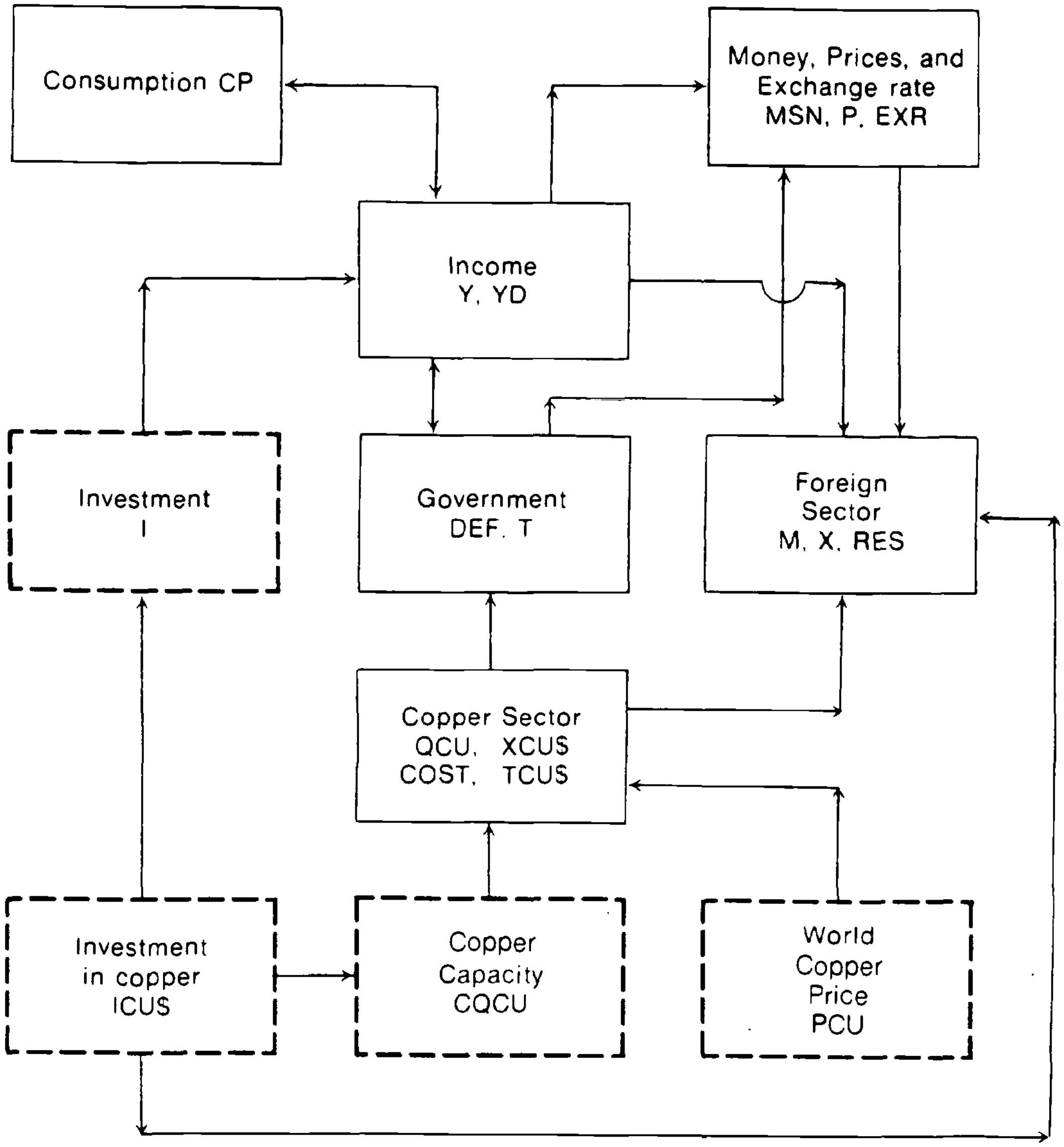

FIGURE 8–1. Sectoral Flows in the Chilean Economy

Noncopper Sector

Consumption

Private consumption (1956–1969, $\bar{R}^2 = 0.95$) (8–1)

$$CP = \underset{(-1.32)}{-1.0236} + \underset{(16.82)}{0.2027}\, YD + \underset{(16.82)}{0.3041}\, YD_{-1}$$

$$+ \underset{(16.82)}{0.3041}\, YD_{-2} + \underset{(16.82)}{0.2027}\, YD_{-3}$$

In this equation real private consumption is a function of permanent or expected real disposable income. It was estimated using the Almon Lag technique with a second degree polynomial and restricted to have a coefficient equal to zero in the periods $t + 1$ and $t - 4$. This procedure causes the coefficients to be symmetrical.[5] The estimated long-run propensity to consume is 1.0137, but it is not significantly different from one. No doubt the Chilean propensity to consume is quite high.[6] However, one suspects that deficiencies in the Chilean national accounts make its estimated value even higher.

Government: Taxes from copper companies appear with the copper sector equations.

Government deficit:

$$DEFN = -TCU\$ \cdot EXRCU - TO \cdot P + CG \cdot P + IGN + SUB + TRGP \cdot P + TRGX \cdot P \quad (8\text{–}2)$$

A positive value of $DEFN$ corresponds to a deficit and a negative value to a surplus.

Other taxes (1950–1971, $\bar{R}^2 = 0.97$) (8–3)

$$TO = \underset{(9.95)}{-2.2802} + \underset{(26.96)}{0.3945}\, Y$$

TO comprises all noncopper government receipts.

Money Supply, Prices, and Exchange Rate:

Change in money supply (8–4)

$$DMSN = 1.5\,(DEFN + NFFEO\$ \cdot EXR + NFFECU\$ \cdot EXRCU) + DMSEX$$

Part of the change in money supply is endogenous and the rest, represented by $DMSEX$, is exogenous. The terms inside the parentheses constitute an approximation of the Central Bank's new money issues. This amount gets amplified by the banking multiplier, which is assumed to be constant at a value of 1.5, an approximation to the sample average. I decided not to get into accounting complications regarding the money supply and instead adjust the endogenous variable by the difference, represented by $DMSEX$. Also note that in Chile banks usually do not hold excess reserves, and thus the multiplier is well determined by the minimum legal required reserves.

Money supply (8–5)

$$MSN = MSN_{-1} + DMS$$

Rate of change in prices (1952–1969, $\overline{R}^2 = 0.79$) (8–6)

$$\dot{P} = \underset{(6.16)}{0.8240}\ (MSN/\dot{P}OP) + \underset{(2.56)}{0.3384}\ (MSN/\dot{P}OP)_{-1} - \underset{(-3.99)}{2.8449}\ (\dot{Y}/POP) - \underset{(-0.80)}{0.5594}\ (\dot{Y}/POP)_{-1} - \underset{(-3.03)}{0.2030}\ DUMSP$$

Chilean inflation has been both high and erratic. The dummy added to the equation (*DUMSP*) corresponds to the beginning of the Alessandri and Frei administrations. It takes the value of one in the years 1960 and 1965 when notable attempts to reduce inflation took place. According to this equation, the increases in money supply translate completely to prices in two periods.[7]

Level of prices (8–7)

$$P = P_{-1}\ (1 + \dot{P})$$

Rate of change of the exchange rate (1952–1969, $\overline{R}^2 = 0.50$) (8–8)

$$E\dot{X}R = \underset{(8.86)}{1.0201}\ \dot{P}/100$$

Exchange rate (8–9)

$$EXR = EXR_{-1}\ (1 + E\dot{X}R)$$

Foreign Sector: Imports

Total imports (8–10)

$$M = MCONS + MKO + MKCU + MINTCU\$\ (EXRCU/P)$$

Imports of consumption goods (1953–1968, $\overline{R}^2 = 0.93$) (8–11)

$$MCONS = \underset{(-0.79)}{-0.1965} + \underset{(2.97)}{0.6}\ MCONS_{-1} + \underset{(2.61)}{0.05}\ (CP + CG) + \underset{(0.71)}{0.0003}\ RES_{-1} - \underset{(-1.03)}{0.0006}\ (PMC\ EXR/P)$$

Note that this is a partial adjustment equation with an adjustment coefficient of 0.4. The level of reserves at the end of the previous period represents the restrictions to imports when foreign reserves are scarce; these are lowered as the conditions improve. At the mean, the long-run elasticities are 2.3 for consumption; −0.6 for relative prices; and 0.09 for reserves. In spite of some low t-statistics, the equation explains well the behavior of *MCONS*. The estimates of the parameters of foreign reserves and prices are approximately the same that appear in many different specifications with higher t-values.

Imports of capital goods (1953–1968, $\bar{R}^2 = 0.88$) (8–12)

$$MK = \underset{(2.26)}{0.46}\, MK_{-1} + \underset{(2.40)}{0.22}\, (IP + ICU\$\; EXRCU/P + IGN/P) + \underset{(2.20)}{0.0008}\, RES_{-1} - \underset{(-1.44)}{0.0004}\, (PMK\; EXR/P)$$

The adjustment coefficient is 0.54, imports adjusting faster than consumption goods. The long-run elasticities are 1.3, 0.2, and −0.4 for investment, reserves, and prices, respectively.

Imports of intermediate goods (1950–1968, $\bar{R}^2 = 0.78$) (8–13)

$$MINT = \underset{(1.50)}{0.102} + \underset{(8.04)}{0.96}\, COEFM$$

The elasticity for COEFM is 1.07 at the mean.

Imports of capital goods for the noncopper sector (8–14)

$$MKO = MK - MKCU$$

Imports of intermediate goods for the noncopper sector (8–15)

$$MINTO = MINT - MINTCU\$\; EXRCU/P$$

Foreign Sector: Exports

Total exports (8–16)

$$X = XO + XCU\$\; EXRCU/P$$

Other Relations in the Foreign Sector

Net flow of foreign exchange in the noncopper sector (8–17)

$$NFFEO\$ = (XO - MCONS - MKO - MINTO)\, P/EXR + OF\$$$

I have added the variable $OF\$$, calculated as a residual, to account for all other noncopper flows and to correct for the data deficiencies.

Change in foreign reserves (8–18)

$$DRES\$ = NFFECU\$ + NFFEO\$$$

Foreign reserves (8–19)

$$RES\$ = RES\$_{-1} + DRES\$$$

Income

Income (8–20)

$$Y = CP + CG + IP + IGN/P + ICU\$\ EXRCU/P + X - M + DSTOCK - INFP + ADJ$$

Disposable income (8–21)

$$YD = Y - TCU\$\ EXRCU/P - TO + TRGP + SUB$$

Copper Sector

Production of copper (1950–1970, $\bar{R}^2 = 0.87$) (8–22)

$$\underset{(20.11)}{QCU = 0.89\ CQCU} + \underset{(1.50)}{0.867\ PCU\$} - \underset{(-4.52)}{86.5\ DUMND}$$

For each level of production capacity the given short-run supply function has a very low price elasticity of 0.07 at the mean. Fisher and Cootner (1971) have estimated a supply function similar to this. Instead of capacity they used one-year lagged production, achieving a short-run and a long-run elasticity of approximately 0.112 and 0.402, respectively. The dummy *DUMND* takes a value of unity in the years immediately before the New Treatment Law of 1955 (1953–1954). In those years the legal treatment of the companies tended to depress production.

Exports of copper (8–23)

$$XCU\$ = QCU \cdot PCU\$ - DSCU\$ - ADXCU\$$$

The variable $ADXCU\$$ adjusts production according to changes in stocks in Chile.

Costs in national currency (1950–1969, $\bar{R}^2 = 0.79$) (8–24)

$$COSTCH\$ = \exp\underset{(-1.12)}{(-7.2} - \underset{(-1.45)}{1.5}\,GORE + \underset{(3.51)}{0.9}\,DUMND)\,(QCU)^{\underset{(3.30)}{2.6}}\,(P/EXRCU)$$

With constant factor costs and a constant grade of ore, this function corresponds to a Cobb-Douglas production function where the sum of the exponents is 1/2.6 (see Dhrymes 1970: 232–34).

Costs in foreign currency (1950–1969, $\bar{R}^2 = 0.67$) (8–25)

$$COSTEX\$ = \underset{(-2.98)}{-\,22.1807} + \underset{(3.88)}{0.5377}\,COSTEX\$_{-1} + \underset{(3.36)}{0.0777}\,QCU$$

The adjustment coefficient is 0.46; the elasticities for production are 1.3 for the short run and 2.8 for the long run at the mean.

Imports of intermediate goods for the copper sector (8–26)

$$MINTCU\$ = 0.5\ COSTEX\$$$

The coefficient of 0.5 on *COSTEX$* was derived from extraneous information.

Copper taxes (1950–1969, $\bar{R}^2 = 0.94$) (8–27)

$$TCU\$ = \underset{(1.19)}{18.5578} + \underset{(12.94)}{0.8134}\,\hat{TR}\cdot PCU\$\cdot QCU - \underset{(-4.10)}{0.3511}\,\hat{TR}\cdot CINDX\cdot QCU$$

The taxation of the companies was basically a profit tax, but given the complication of the tributary system, a stochastic specification was chosen with both a proxy for the tax rate ($\hat{TR}$) and for the tax base (value of production minus costs). The costs are based on a unitary cost index (*CINDX*).

Net flow of foreign exchange from the copper sector (8–28)

$$NFFECU\$ = TCU\$ + COSTCH\$ + 1/2\ ICU\$ + WUS\$$$

Control Solution

By setting the equation residuals equal to zero, one can solve the model using the Gauss-Seidel iterative method. Using for the lagged endogenous variables the solution values, a dynamic solution is obtained for a given number of years. The control solution of the model is a dynamic deterministic solution for the period 1956–1968. The model converges in six to eight iterations. Table 8–1 summarizes the mean, root mean square, and the ratio of these two magnitudes for the control solution. The solution is quite satisfactory in the sense that it approximates the actual values for the major macroeconomic aggregates: income (*Y*), disposable income (*YD*), and private consumption (*CP*), and for the two important variables in the copper sector: production (*QCU*) and exports of copper (*XCU$*). For the remainder of the variables in the model the results are satisfactory.

The net flow of foreign exchange variables do much better than expected. The net flows from the copper sector (*NFFECU$*) appear to be consistently overestimated and from the noncopper sector (*NFFEO$*) to be consistently underestimated. These two variables

Table 8–1. Mean, Root Mean Square Error, and Ratio of the Control Solution

	Mean	*RMS*	*RMS/MEAN*
1 CP	11.5649	0.518	0.045
2 DEFN	0.3937	0.292	0.742
3 TC	3.8032	0.296	0.078
4 DMS	0.3381	0.385	1.139
5 MS	1.2490	1.445	1.157
6 $\dot{P}$	30.0651	13.419	0.446
7 P	0.6972	0.100	0.143
8 $E\dot{X}R$	0.3492	0.194	0.556
9 EXR	2.2658	0.825	0.364
10 M	2.1699	0.262	0.121
11 MCONS	0.7308	0.085	0.116
12 MK	0.7836	0.194	0.248
13 MINT	0.6556	0.064	0.098
14 MKO	0.7119	0.194	0.273
15 MINTC	0.6013	0.068	0.113
16 X	2.1619	0.309	0.143
17 NFFEC$	−321.1850	105.176	0.327
18 DRES$	6.0154	96.906	16.110
19 RES$	99.3691	163.995	1.650
20 Y	15.5254	0.633	0.041
21 YD	13.1166	0.417	0.032
22 QCU$	490.1299	20.907	0.043
23 XCU$	326.8152	15.431	0.047
24 COSTCH$	156.9230	54.160	0.345
25 COSTEX$	32.0153	3.809	0.119
26 MINTCU$	16.0077	1.904	0.119
27 TCU$	115.8615	21.280	0.184
28 NFFECU$	327.1973	56.466	0.173

Source: Based on the author's computations.

perform much better after readjusting them by using a better definition of their components. That is, one can subtract half of the investment in copper from the first variable and add it to the second, following the original model specification. This redefinition does not affect the rest of the results because these flows are always aggregated together. The variables subject to larger errors are those formed as small differences of large variables, that is, government deficit (*DEFN*), change in money supply (*DMS*), and change in foreign reserves (*DRES*\$), and those with accumulated errors, that is, money supply (*MSN*) and foreign reserves (*RES*\$).

Multiplier Analysis

To test the sensitivity of the model when changes in some exogenous variable takes place, I have made a series of simulations of the noncopper sector. The variables selected for the analysis are of a traditional Keynesian type: change in investment, change in taxes, autonomous change in private consumption, and change in exports. The only link from the noncopper to the copper sector is through the exchange rate. Had it been exogenous, the noncopper sector could have been simulated separately. To interpret the results, one has to keep in mind that the model assumes that aggregate supply adjusts immediately to aggregate demand.

1. *Once and for all increase in government investment*

With a shock consisting of a once and for all increase in government investment of E°10 million I found an investment multiplier ($MIG = \Delta Y/\Delta IG$) of 1.3. Seventy percent of the income impact takes place in the first year; the complete impact appears after the fourth year. The low value of the multiplier, which contrasts with the very high propensity to consume, is explained by the high tax rates (40 percent) and the high response of imports to changes in income.

2. *Increase in government investment*

In this case the shock, consisting of an increase in government investment of E°10 millions (in 1965 values), is repeated every year, starting in 1956. The average increase in income is E°20 million (1965). The multiplier for this type of shock, defined as the ratio of the average increase in income to the average increase in government investment, is equal to 2. But during the simulation period, income has increased at a declining rate, suggesting a higher multiplier over a longer period, maybe around 2.6. The level of prices is consistently lower than in the control solution because the effect of income is stronger than the effect of the increase in money supply. The increase in government deficit (*DEFN*) is not as high as the increase in government investment because receipts are increased with income.

3. *Increase in noncopper taxes*

The shock is an increase of E°100 (1965) every year, starting in 1956.[8] Decrease in income is an average of E°180 million. Nevertheless, the lower government deficit translates into a lower money supply; the level of prices is higher than in the control solution because of the decrease in income. It is very interesting to observe the final effect on noncopper taxes. In the first period the decrease in income is small; therefore the negative indirect effect on noncopper taxes is also small. Instead of the E°100 million intended, taxes increase by only E°91 million in the first year. As the impact on income continues to increase, the negative effect on taxes becomes larger. The government's attempt to increase taxes fails in the long run. In the last year the increase is only E°2 million out of the E°100 million intended.

4. *Autonomous increase in private consumption*

The shock is an increase of E°1 billion (1965) every year, starting in 1956. The average multiplier and the last year multiplier are virtually the same as in the second simulation (government investment), 2.0 and 2.5, respectively. The government deficit decreases very strongly because receipts increase with income. The lower increase in money supply and the higher income act together to achieve a lower price level.

5. *Increase in noncopper exports*

With an increase of E°100 million in noncopper exports every year starting in 1956, income increases during the first four years, then decreases from 1960 to 1962, and finally increases slightly from 1963 to the end. The average increase in income is E°21.7 million; the first year increase is E°112 million, compared with only E°2 million in 1968. This phenomenon is explained by the rapid increase in imports. What happens in the economy is that the foreign reserve position improves as exports increase, but imports, which are very sensitive to the level of reserves, start to increase also, counteracting in part the effect of exports in aggregate demand.

Summary of Results of the Multiplier Analysis: The traditional Keynesian multiplier is quite low because of the high leaks, the high tax rate, and the high response of imports to income. The multiplier for continuous shocks is possibly twice as high. If income is actually constrained by demand, prices should decrease as deficit government expenditures increase. In the long run the government fails to increase taxes if the new receipts are sterilized. Finally, imports, which are very sensitive to increases in foreign reserves, counteract very quickly the effect on aggregate demand caused by increases in exports.

THE IMPACT OF WORLD COPPER PRICE CHANGES ON THE CHILEAN ECONOMY

The price of copper is one of the variables whose impact on the Chilean economy is of primary interest. Its fluctuations in the world market are very wide and have a strong impact on the highly dependent Chilean economy. In our model the price of copper is taken as exogenous, but one can simulate different prices and see what their impact would have been. This study could be complemented with a study on the world market capable of forecasting the world price.

In recent years Chile has been selling its copper at a price called the "price of Chilean Producers," fixed by the Chilean Copper Corporation (CODELCO). This price has been temporarily set equal to the price at the London Metal Exchange. Although a change in this policy is not foreseen in the near future, this has not been the situation in the past. During the second World War, all the Chilean copper was exported to the United States, which resulted in a low price. After the end of the war, the price ceiling was removed, and Chilean copper was sold at a much higher price, fixed by the large U.S. producers. At the beginning of the Korean War the U.S. government fixed the price again, but this time there was an agreement between the United States and the Chilean government to set the price 3 cents per pound higher (27 cents per pound instead of 24 cents). The additional 3 cents did not go to the companies, but directly to the Chilean government. After a year under this agreement, Chile decided not to renew it and began to fix the price directly. The Chilean copper was sold at more than 35 cents per pound, but the companies continued to receive 24 cents. This experience did not end happily. Chile was unable to adapt to the new situation when the demand pressure slowed down. Stocks started to pile up. Finally, the New Treatment Law of 1955 allowed the companies to sell the copper directly, but the government reserved the right to intervene to insure that they were selling at the highest market prices.

Simulation analysis is used to evaluate the impact of price changes on copper production (QCU) and on copper exports ($XCU\$$). For example, had the copper price been 10 cents higher every year during the simulation period, the copper supply would have been 8,674 metric tons higher every year, and the value of the exports of copper would have been an average of \$115.1 million higher (in 1956—\$102.3 million higher and in 1968—128.2 million higher). Similarly, the cost of production in foreign currency (*COSTEX\$*) is easy to calculate, and consequently the imports of intermediate goods (*MINTCU\$*). But to see the effect of a price change on the cost in national currency (*COSTCH\$*), it is necessary to make use of the complete model, which computes a new exchange rate.

It is much more complicated to see the effect on the rest of the economy, which not only requires a simulation with the complete model, but also assumptions about how the Chilean government is to react when prices change. Many of these assumptions are built into the model, one of the most important being the way of regulating imports according to the foreign reserve constraint. The given specification of the import functions seems to describe well the government reaction during the simulation period. But this is a policy tool whose use is very important in the design of governmental economic policy. It has been and continues to be greatly discussed among Chilean economists. The present contribution to this discussion is to show what is likely to happen to aggregate demand, based on the underlying assumptions of the model.

Another important decision that must be made by the government is how to use the receipts from an increase in the price of copper (in this case set at 10 cents). The model assumes that the Central Bank buys the foreign currency from the government, who uses it to relieve its deficit (the budget is not separated into national and foreign currency). This appears to be so because of the need to counteract inflation. The simulations presented here are based on two alternative assumptions: (1) the government acts the way described by the model, sterilizing the additional receipts when copper price increases; and (2) the government increases its expenditures by exactly the same amount as the additional receipts. The results obtained are radically different.

1. *Government maintains the original expenditures*

In this case GNP increased at the beginning of the period, but then decreased after 1960. The average decrease for the period was E°12.7 million (1965). The increase in exports is counteracted in two ways: (1) by an increase in imports, owing to a better situation in the foreign reserves, and (2) by the sterilization of the portion of the increase in exports corresponding to higher taxes from copper. The increase in imports alone is not enough to produce the decline in GNP because it is only part of the increase in exports. Alternatively, the sterilization of the tax increases alone is not enough to produce the decline in GNP, because what is being sterilized is again part of the increase in exports.

But the sum of these two effects is sufficient to produce the decrease in GNP found in this simulation.

2. *Government increases its expenditures by the amount of the additional receipts*

In this case the only counteracting effect is that of the induced increase in imports. A higher GNP occurs every year during the simulation period. The average increase is E°290.3 million (1965).

THE IMPACT OF GOVERNMENT POLICY CHANGES

Let us now analyze the impact of the three macro policy variables: changes in investment, taxation, and the exchange rate. The government could fix the tax rates of the companies and could impose discriminatory exchange rates on them. But these two policies would affect the willingness of the companies to invest in Chile. Many times during the sample period, negotiations between the government and the companies took place. On two occasions these negotiations changed substantially the legal treatment of the companies. First in 1955 with the New Treatment Law and later, in the second half of the 1960s, with the process of partial nationalization. Sometimes negotiations failed, as at the beginning of the 1960s, when the companies wanted to expand production capacity. They requested a guarantee by the government not to increase the tax rates for a long period of time. Since the government did not accept this condition, expansion did not take place.

The practice of fixing lower exchange rates for the copper companies was ended by the New Treatment Law of 1955, but it was again applied, to a lesser extent, in the 1960s. For example, in 1951 the average exchange rate of copper was E°0.019 per dollar, and for the rest of the economy it was E°0.057. Since the companies purchase all their imports with their own exchange, the real discrimination would be the difference between the actual exchange rate for the copper sector and the parity exchange rate. I presently refer only to the nominal discrimination.

Increasing the tax rate was always a temptation to the Chilean government. It would alleviate the government deficit and increase the inflow of foreign exchange. From the point of view of internal politics, it would be a popular measure. Of course there was the fear that the expansion of production capacity would be inhibited, but this temptation was not always resisted. For example, in the early 1960s a devastating earthquake was a reason to establish an additional reconstruction tax on the copper companies.

Of these three variables, the tax and the exchange rates are properly government policy variables. Investment was a variable controlled by the companies although it was influenced by the government policies. The Chilean government could also invest in copper, thus making investment also a government policy variable.

Here we do not study the interrelationship between these three policies, but simply conduct the simulation analysis by assuming different relations between tax rates and investment, and between exchange rates and investment. To avoid varying the relation between investment and changes in production capacity, two additional assumptions are made:

1. Assumption 1: every million dollars of investment increases production capacity by 500 metric tons per year.
2. Assumption 2: every million dollars of investment increases production capacity by 1000 metric tons per year.

These values come from the observation of specific expansion programs undertaken in Chilean large-scale copper mining. For large projects, it seems that the following patterns appear to exist. A lag of two years occurs until investment becomes materialized in increased production capacity; and one-half of the investment is spent on imports of capital goods and one-half on payments in Chile.

Simulations follow in seven groups. In the first three groups I change only one variable, assuming that the other two remain unchanged. In the last four, changes in investment are assumed in response to either discriminatory exchange rates or changes in the tax rate. The seven groups of simulations are as follows:

1. Higher investment
2. Higher tax rates
3. Discriminatory exchange rates
4. Discriminatory exchange rates and lower investment
5. Higher tax rates and lower investment
6. Tax rate equal to 100 percent and zero investment by the companies
7. Tax rate equal to 50 percent and higher investment

Because of space limitations, only a sample of the total simulation runs can be discussed. The results selected are based on assumption 1. In addition government expenditures do not vary with changes in government receipts.

1. *Higher investment*

The impact of the new investment on the economy will depend not only on its magnitude, but also in the way it is spread over time.

Results are presented for two cases: (a) that the total investment is completed in one year, and (b) that the investment is equally distributed among the simulation periods.

a. *Additional investment of $200 million in 1956*

Beginning with the third year, production capacity will be 100 thousand metric tons higher than historical levels, and production will be 89,100 metric tons higher. Exports will increase between 50 and 105 million dollars. Taxes on copper will average $15 million higher. The accompanying improvement in foreign reserves will induce an increase in imports. As the government sterilizes the new receipts, the combined counteracting effect produces a decrease in aggregate demand averaging E°200 million (1965). The only years in which income increases are the first, third, and fourth. In the first year investment increases, but neither imports (except capital goods for the copper sector) which react with a lag to the change in reserves nor taxes from copper sales increase. In the second year there is no investment injection; production capacity has not yet increased; but imports are higher and so are the noncopper taxes. This produces a decline in aggregate demand. In the third and fourth years we already have the increase in exports that predominate over the counteracting forces. In the fifth year, however, income is lower than in the control solution.

b. *Additional investment of $20 million every year*

The difference from the previous simulation is that new investment now enters the economy every year. Income increases until 1962 and decreases from 1963 on. The result is an average decrease of E°46 million (1965). The depressing forces take more time to predominate.

2. *Higher tax rates*

An additional tax of 10 percent introduced to our model through the proxy for the tax rate (*TR*) will have a variable effect on *TCU*$, because this variable is determined stochastically. The increase in taxes will be between 9 percent and 14.5 percent, with an average of around 12 percent. Income decreases an average of E°95.4 million (1965). Both foreign reserves and imports are higher during the simulation period. The government gets additional receipts that are sold to the Central Bank and used to diminish the deficit. But as income is depressed, so are noncopper taxes; the final result is a very slight decrease in government deficit.

3. *Discriminatory exchange rates*

With a lower exchange rate, the companies have to spend more dollars to cover the same expenses in national currency. Thus, an exchange rate 50 percent lower would have meant an increase in the dollar value of the costs in national currency (*COSTCH$*) between $123.4 million and $293.6 million, averaging around $200 million. With this additional inflow of foreign exchange, reserves are increased substantially. At the end of the period, in spite of the high increase in imports, the level of reserves is nearly five times that in the control solution. Aggregate demand diminishes an average of E°847.5 million (1965) because of the increase in imports.

4. *Discriminatory exchange rates and lower investment*

The effect of a discriminatory exchange rate is now made dependent on how the companies would have reacted through their investment. Because it is difficult to guess the reaction of the companies, different assumptions were made about the decrease in investment. The magnitude of the results changes, but not their nature. Suppose that an exchange rate 50 percent lower would have induced the companies to invest 20 percent less in Chile. The result would have been to end up in 1968 with a production decrease of 18.6 percent. Had the investment been 50 percent lower, production in 1968 would have been 46.8 percent lower. In the first case the dollar value of the costs in national currency would still be higher, but this increment averaging $80 million is lower. In the second case this variable is higher during the first four years and lower than in the control solution from then on. Returning to the first case, the level of reserves is higher for the whole period except for the last year. This produces an increase in imports, which depresses income by E°500 million (1965). In 1968 imports are $41 million lower, a consequence of the lower income.

5. *Higher tax rates and lower investment*

If the introduction of an additional tax of 10 percent had induced the companies to decrease investment by 20 percent, production would have declined an average of 52.2 thousand metric tons. In this case copper taxes increase the first six years, but later production is sufficiently lower to cause them to decrease, resulting in an average decrease of $0.4 million. On the other hand, the lower production implies a lower cost in national currency of $57.4 million. The result is a great deterioration of foreign reserves, which in turn induce imports to decrease significantly. The lower investment is able to produce a very slight decrease in income during the first three years, but afterward income increases, ending with an average increase of E°65 million (1965).

6. *Tax rate of 100 percent and zero investment by the companies*

A 100 percent tax rate is very similar to nationalizing the copper companies without giving them any compensation. Thus, the proxy for the rate (*TR*) is set equal to 100 percent and this comes very close to taxing the entire profits of the companies. Of course the companies do not make any new investment in Chile. In this group two cases are analyzed: (a) investment is zero, and (b) the government obtains money from abroad and makes an investment of $100 million in 1956.

a. *Zero investment*

Production declines an average of 41.5 thousand metric tons. In spite of this reduction, the government gets additional receipts from copper averaging $28.8 million. This increase in taxes is too low to prevent the deterioration in the level of foreign reserves, which induces a decline in imports. But the decline in disposable income, together with the decline in exports, produces a decrease in aggregate demand.

b. *Government invests $100 million in 1956*

Production capacity is higher between 1958 and 1962, but it is lower from 1963 to the end. The average loss in production is 3.8 thousand metric tons. It is assumed that government finances the investment with a long-term foreign loan so money is not taken from reserves. Despite foreign reserves being higher most of the years as taxes are increased, this increase is not enough to keep imports higher, because the decline in disposable income tends to predominate in depressing imports. The decline in exports and investment is stronger than the decline in imports, giving a net decrease in income.

7. *Tax rate equal to 50 percent and higher investment*

A tax rate of 50 percent would probably have been an incentive to the companies to invest more. Being conservative, let us assume that investment would have been 10 percent higher. In this case production would increase, ranging from 4.2 thousand metric tons in 1958 to 49.2 thousand metric tons in 1968, with an average of 26.3 thousand metric tons. But as the tax rate is lower, there is an average decrease in taxes of $21.7 million. In terms of foreign reserves, the increase in production is not enough to compensate the lower tax receipts, but the increase in disposable income, perhaps together with the time structure of the increases and decreases in reserves, produces an average increase in imports. Exports increase far more than imports, which together with the increase in disposable income and investment, produce an increase in income.

SUMMARY AND CONCLUSIONS

I have developed a model of the Chilean economy describing the interrelationship between the copper sector and the rest of the economy.

The model used for the noncopper sector is essentially Keynesian. This means that the emphasis is placed on the demand side. Aggregate demand is what determines real income; aggregate supply plays the passive role of adjusting to aggregate demand. The validity of the results has depended, among other things on (1) the state of the economy in terms of the responsiveness of aggregate supply to adjust to increases in aggregate demand, and (2) the realism of the assumptions made regarding government behavior. When aggregate demand decreases, as in most of the simulations, one may well expect that supply decreases will follow. Although the specification of the model has not permitted the testing of more sophisticated assumptions about government behavior, further development of the model could easily accomplish this task. In effect, simulation analysis conducted along these lines could be of great help to the Chilean government in designing its copper related policies.

NOTES

1. Jere Behrman (1976) has constructed a larger, more general model of the Chilean economy that could be used in future exercises.

2. Some of the advantages and disadvantages of establishing such a linkage are reported in Chapter 7.

3. Behrman (1976) justifies using primarily ordinary least squares in estimating his model for the Chilean economy in the following way:

> The expected returns of adopting more sophisticated methods are less than the expected costs of doing so given the nature of the data, some questions about the robustness of alternative estimators, and the opportunity costs of sophistication in estimation procedure in terms of exploring various model structures.

4. Using 2SLS:

$$\begin{aligned} CP = & -2.0277 + 0.2198\ YD + 0.3297\ YD_{-1} \\ & \ (-2.79) \quad (19.53) \qquad (19.53) \\ & + 0.3297\ YD_{-2} + 0.2192\ YD_{-3} \\ & \ (19.53) \qquad\quad (19.53) \end{aligned}$$

$$\bar{R}^2 = 0.95$$

The long-run propensity to consume from this equation is 1.0990.

5. In this case

$$P(\tau) = \beta_0 + \beta_1\tau + \beta_2\tau^2 \qquad \tau = 0, 1, 2, \ldots, n$$

where n, the maximum lag, is 3. Constrained to have $P(t + 1) = P(t - n - 1) = 0$, we have

$$P(\tau) = -\beta_2 \left| n + 1 + n\tau - \tau^2 \right|$$

See Dhrymes (1971).

6. Jere Behrman (1976) estimated a log-run propensity equal to 0.956.
7. The sum of the relevant coefficients is around 1.15, but not significantly different from one.
8. To indicate that most of the solutions values are based on 1965 values, I simply have placed the base year in parentheses (1965) where relevant.

APPENDIX

1. *Endogenous Variables**

	Name	Description	Units	Source
1	CP	Private Consumption[1]	Billion E°1965	Nat'l Acct.
2	DEFN	Government Deficit[5]	Billion Current E°	1
3	TO	Other Taxes[6]	Billion E°1965	2
4	DMSN	Change in Money Supply	Billion Current E°	
5	MSN	Money Supply (M_1)[7]	Billion Current E°	3
6	$\dot{P}$	Rate of Change in GNP Deflator	Percentage	
7	P	Implicit GNP Deflator[8]	1965 = 1	4
8	$\dot{EXR}$	Rate of Change in Exchange Rate	Per Unity	
9	EXR	Exchange Rate[9]	E° per US$	5
10	M	Imports	Billion E°1965	Nat'l Acct.
11	MCONS	Imports of Consumption Goods[10]	Billion E°1965	6
12	MK	Imports of Capital Goods[10]	Billion E°1965	6
13	MINT	Imports of Intermediate Goods[10]	Billion E°1965	6
14	MKO	Imports of Capital Goods for Noncopper[11]	Billion E°1965	7
15	MINTO	Imports of Intermediate Goods for Noncopper[12]	Billion E°1965	8
16	X	Total Exports[1]	Billion E°1965	Nat'l Acct.
17	NFFEO$	Net Flow of Foreign Exchange from Noncopper Sector[13]	Million US$	9
18	DRES$	Change in Foreign Reserves	Million US$	
19	RES$	Foreign Reserves[14]	Million US$	10
20	Y	Gross National Product	Billion E°1965	Nat'l Acct.
21	YD	Disposable Income[15]	Billion E°1965	11
22	QCU	Production of Copper Net Content[2]	Thousand MT	Codelco
23	XCU$	Exports of Copper. Fob.[3]	Million US$	Bal. de Pagos
24	COSTCH$	Costs of the Copper Company paid in National Currency[2]	Million US$	Codelco
25	COSTEX$	Costs of the Copper Company paid in Foreign Currency[2]	Million US$	Codelco
26	MINTCU$	Imports of Intermediate Goods for Copper Sector[16]	Million US$	12
27	TCU$	Taxes from Copper Comp.	Million US$	Codelco
28	NFFECU$	Net Flow of Foreign Exchange from the Copper Sector[17]	Million US$	13

2. *Exogenous Variables*[*]

1	ADJ	Adjustment for Changes in the Terms of Trade[1]	Billion E°1965	
2	CG	Government Consumption[2]	Billion E°1965	
3	CINDX	Index of Principal Metal Mining Expenses[4]	1958 = 100	
4	COEFM	Imports of Intermediate Goods Required According to Input-Output Table Coefficients[18]	Million E°1965	
5	CQCU	Production Capacity of the Copper Companies. Net[19]	000 Metric Tons	
6	OF$	Other Flows of Foreign Exchange[20]	Million US$	
7	DMSEXN	Exogenous Change in Money[21] Supply	Million Curr. E°	
8	DSTOCK	Change in Stocks[1]	Billion E°1965	Nat'l Acct.
9	DSCU	Change in Stocks of Copper in Chile[3]	Million US$	Bal. de Pagos
10	DUMND	Dummy, Pre-New Deal Years	1953, 1954 = 1	
11	EXR	Exchange Rate for National Accounts[1]	E°per US$ 1	ODEPLAN
12	EXRCU	Average Exchange Rate for the Copper Companies[2]	E°per US$ 1	CODELCO
13	GORE	Grade of ore of Kennecott's mines in Chile[22]		18
14	IGN	Government Investment[23]	Billion Curr. E°	19
15	ICU	Investment in Copper[24]	Million US$	20
16	INFP	Net Payment to Foreign Production Factors	Billion E°1965	Nat'l Acct.
17	IP	Private investment[25]	Billion E°1965	21
18	MKCU	Imports of Capital Goods for the Copper Sector[26]	Billion E°1965	22
19	MS	Money Supply (M_1)	Billion E°1965	
20	PCU	Price of Copper[29]	US$ per pound	23
21	PMC	Unit Value Index of Imports of Consumption Goods	1947 = 100	Bal. de Pagos
22	PMK	Unit Value Index of Imports of Capital Goods	1947 = 100	Bal. de Pagos
23	POP	Population[28]	Million of Persons	24
24	RES$	Foreign Reserves	Million US$	
25	SUB	Government Subsidies	Billion E°1965	Nat'l Acct.
26	$\widehat{TR}$	Proxy for Tax Rate[29]	Per Unit	25
27	TRGP	Net Transfers from Govt. to Households[1]	Billion E°1965	Nat'l Acct.
28	TRGX	Net Transfers from the Govt. Abroad[1]	Billion E°1965	Nat'l Acct.
29	WUS	Wages Pd. in Foreign Currency by Copper Companies[2]	Million US$	CODELCO
30	XO	Noncopper Exports[30]	Billion E°1965	
31	ADXCU	Adjustment for Copper Export	Million US$	
32	DUMSP	Dummy, Stabilization Policies		

[*]*Notes on the Data Sources*

[1]ODEPLAN (annual).

[2]CODELCO: Data furnished by CODELCO (Copper Corporation of Chile).

[3]Balanza de Pagos: *Balanza de Pagos de Chile* (annual).

[4]U.S. Bureau of Mines. Annual. The national accounts of 1950–1959 were adjusted because of changes in compilation.

[5]Calculated as the change in total credit received by the government. $DEFN = CR - CR_{-1}$.

[6]Calculated as total government receipts minus taxes from copper; TO = Gov. Receipts $- TCU\$ \cdot EXR/P$.

[7]Part of this series was taken from French-Davis (1971). It was completed with data from the *Boletin Mensual*, Central Bank of Chile. It corresponds to the definition of M_1.

[8]Calculated as nominal income divided by real income; $P = Ynom/Yreal$.

[9]Corresponds to the exchange rate used in the Chilean national accounts, furnished by ODEPLAN.

[10]The percentages calculated from the *Balanza de Pagos* were applied to the total imports of the national accounts.

[11]Calculated as total imports of capital goods minus imports of capital goods for the copper sector; $MKO = MK - MKCU$.

[12]Calculated as total imports of intermediate goods minus imports of intermediate goods for the copper sector; $MINTO = MINT - MINTCU\$ - EXR/P$.

[13]Calculated as noncopper exports minus noncopper imports plus other flows in the noncopper sector.

[14]From French-Davis.

[15]Calculated as income minus government receipts; $YD = Y - TO - TCU\$ \cdot EXR/P + TRGP + SUB$.

[16]Calculated as 1/2 of the costs of the copper companies paid in foreign currency. These costs are distributed more or less in equal parts between imports of intermediate goods and other costs, according to the partial date we were able to get; $MINTCU\$ = 0.5\ COSTEX\$$.

[17]Calculated as taxes from copper plus costs of the copper companies paid in national currency plus investment in copper plus wages paid in foreign currency in the copper sector (WUS$).

[18]The coefficients of imports of intermediate goods were applied to the value added of each sector. The coefficients are the following: Agriculture: 0.00949; Mining: 0.0558; Construction: 0.0376; Manufacturing: 0.1047; Transportation: 0.0172; Electricity, Gas and Water: 0.0394; Services: 0.00214.

[19]The method of the "trend through peaks" was used.

[20]Calculated as a residual from $DRES - NFFECU\$ - NFFEO\$$.

[21]Calculated as a residual from the money supply equation.

[22]From Kennecott's Reports to the Stockholders.

[23]Calculated as government savings minus government deficit; IGN = AGN − DEFN.

[24]From the Chilean Senate's Information Office.

[25]Calculated as total investment minus government investment minus investment in copper; $IP = I - ICU\$ \cdot EXR/P$.

[26]Calculated as 1/2 of investment in copper. From the observation of specific investment projects in the copper sector, I found that around half is spent on imports of capital goods and half is brought to the country as foreign exchange to buy national goods and services.

[27]Calculated as the value of sales divided by the quantity. It is an average price in US$ per pound of copper.

[28]Provided by ODEPLAN.

[29]The tax rates for each of the companies were first calculated following the taxing laws; then a weighted average of the three tax rates was constructed.

[30]Calculated as total exports minus copper exports; $XO = X - XCU\$ \cdot EXR/P$.

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