Testing for Market Power under the Two-Price System in the U.S. Copper Industry

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Abstract

Before 1978, most of the U.S. domestic copper production and an important fraction of the imports were traded at a price set by the major U.S. producers. Simultaneously, the rest of the world was trading copper at prices determined in auction markets. This two-price system ended in 1978, when the largest U.S. producers began using the Comex price of refined copper as a benchmark for setting their prices. Using this regime shift I test empirically the competitive behavior of the US copper industry before 1978. The results show that copper prices were close to the ones predicted by a competitive model of the industry.

JEL: D40, D43, L13, L61, and L72.

Keywords: Copper Industry, Market Power.

1 Introduction

In general, the transactions between buyers and sellers of refined copper in the world are done using spot prices, which are determined in auction markets like the London Metal Exchange (LME) or the New York Commodity Market (Comex). However, before 1978, the

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domestic production and an important fraction of the imports[1] of refined copper in the U.S. were traded at a price known as the U.S. producer price, which was set by the major U.S. producers.

There is also some evidence suggesting there was price collusion among U.S. copper producers during the existence of this two-price system. There are, for example, several periods of time with a constant price of copper in the U.S. (1951-52 and 1962-63 the longest ones) while the LME, a competitive free market, shows many fluctuations. There were also some long periods of time when the domestic prices were much higher than the international prices. During the 1974-76 period, for example, the difference between the U.S. producer price and the LME price was 9¢/lb. on average, and the average charges for freight, insurance and storage for copper sold in London were around 2-3¢/lb. These facts and the behavior of the U.S. copper producers were investigated by the U.S. Congress and the U.S. Government[2], but no conclusions regarding the existence and exercise of market power were reached and no actions were taken.

The two-price system officially ended in may of 1978, when Kennecot, the largest U.S. domestic producer, announced that it would start using Comex prices as a reference for its contracts.

An important effort in the literature has been devoted to explain why the U.S. copper industry enjoyed monopoly power before 1978. Less work has been done trying to test if that

[1] During the period 1950-1978, imports represented, on average, 9% of U.S. refined copper consumption and around 93% of these imports came from U.S. subsidiaries.

[2] See the "Report of the Subcommittee on Copper to the Cabinet Committee on Copper", Washington, may 13, 1970; see also "Copper: Quarterly Industry Report", U.S. Department of Commerce, Business and Defense Services Administration, Vol. 16, No. 2, January 1970.

monopoly power was actually exercised or not and up to what extent.[3] In this paper I test empirically the competitive behavior of the US copper producers. Even though the copper industry is highly concentrated and with important sunk costs, the results show that the U.S. producer prices were, on average, very closed to the ones predicted by a competitive behavior of the industry.

The rest of the paper is organized as follows. Section 2 describes the U.S. copper industry and discusses the two-price system. Section 3 explain the specifics of the copper industry and presents the models of demand and supply of copper. Section 4 explains the data. Section 5 shows the empirical results and Section 6 concludes.

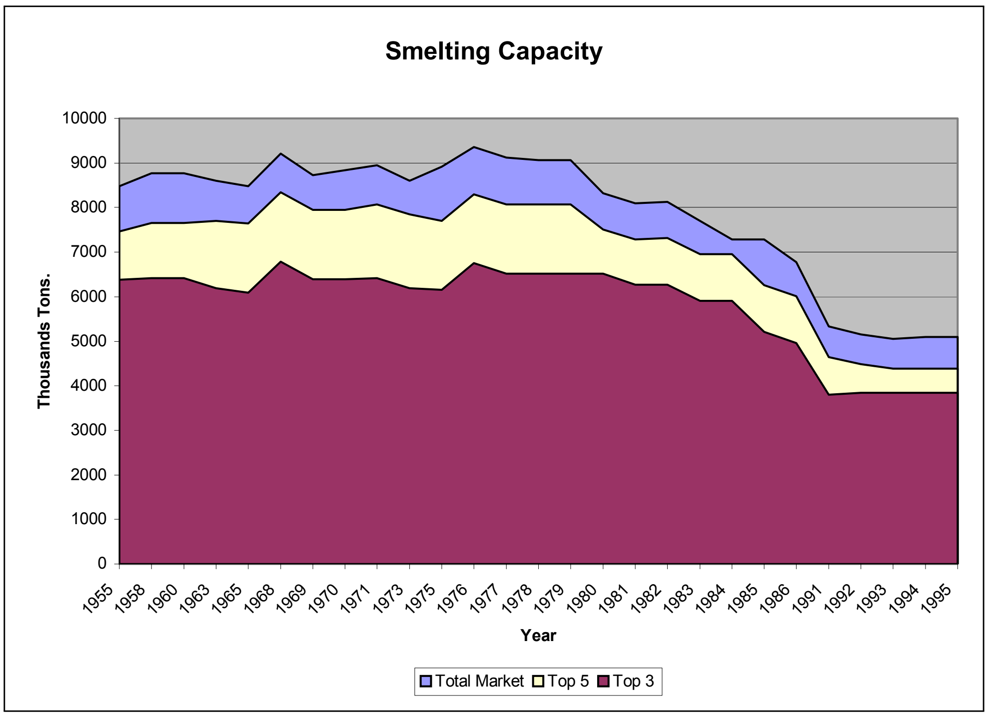
2 The U.S. Copper Producers

The production of refined copper in the U.S. has always been concentrated in a few companies. During most of the post WWII period, the U.S. copper industry has had only three major producers: Anaconda, Kennecott, and Phelps Dodge. These three companies are integrated producers, who supply their smelters and refineries with company-mined ores. There exist also the so-called "custom smelters" companies, which refine copper produced by non-affiliated firms. There have been two major custom smelter firms during the period 1950-95: Amax and Asarco. Hence, even when the custom smelter firms are considered as relevant actors in this

[3] The only study I am aware of is the one by Hartman, Bozdogan and Nadkarni (1979). They simulate three pricing strategies: average variable cost pricing (P=AVC), full cost pricing (P=ATC), and collusive pricing (MR=MC). Then, the results of the simulation are compared with actual prices to conclude that the full cost pricing strategy is the strategy that best approximates actual prices.

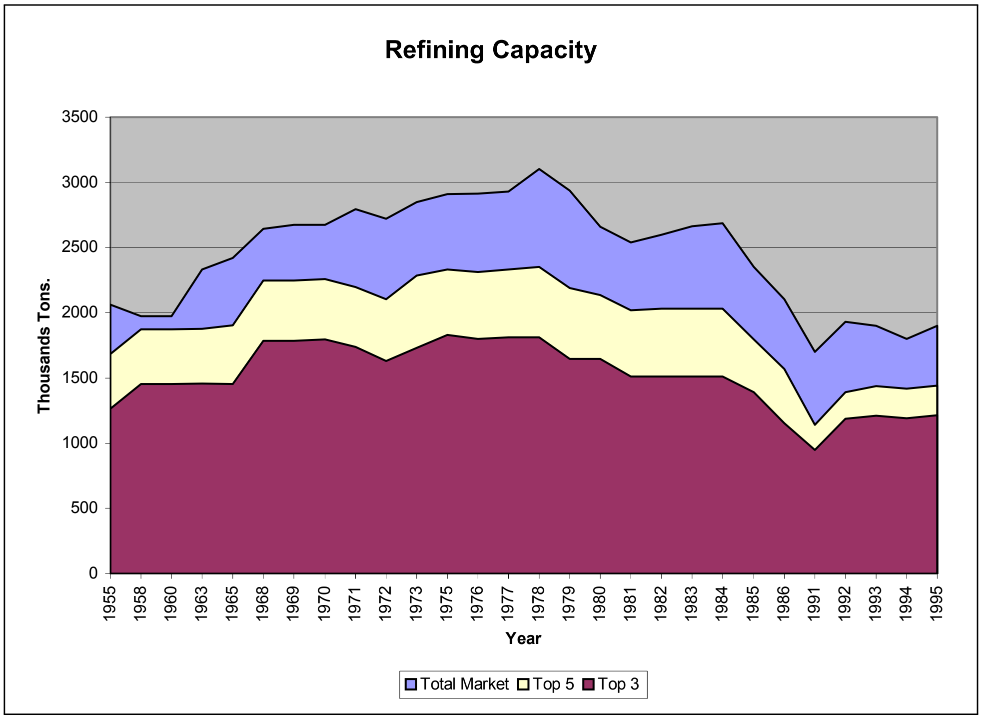
market, we are speaking of only five firms at most.[4] Figures 1 and 2 show the smelting and refining capacity of the top three and top five companies respectively, compared to the total industry for the period 1955-95. The percentages of the total industry capacity owned by the three biggest firms are, on average for the whole period, 73.8% for smelting and 61.9% for refinery. The same percentages for the five largest firms are 88.9% and 79.3%.

Figure 1:



[4]There is no periodical public information about production by firm that would allow me to quantify the degree of concentration in the industry and its evolution, but there exist such data for capacity.

Figure 2:



2.1 The Two-Price System

Most of the transactions between producers and consumers of refined copper are done through one-year contracts that specify a monthly quantity with a price equal to the spot price at the day of delivery.[5] As it was mentioned before, the spot price used in these contracts is the price determined in auction markets. However, before 1978, domestic and imported refined copper[6] in the U.S. was traded at a price set by the major U.S. producers.

[5] A typical contract specifies the total annual tonnage, the monthly delivery and the point of delivery. The price is not specified, but stated as "the seller's price at the time of delivery", where usually the LME or Comex spot price is specified as the seller's price.

[6] Before the mid 70's the major U.S. producers also owned most of the large mines in South-America, Africa and Oceania. Therefore, a considerable proportion of imports were actually from U.S. subsidiaries in foreign countries.

Why did this two-price system exist and why did not arbitrage equalize the two prices? The most common explanation found in the literature (Fisher, Cootner and Baily (1972), Mackinnon and Olewiler(1980), Richard (1978),Vial (1988,1992)) for the existence of the two-price system, is that U.S. producers set the price to reflect a sustainable and profitable long-run level of copper prices (taking into account their own resulting supply decisions). The idea behind this argument, is that copper producers consider that a stable price will lead to a higher present value of profits than a volatile price that fluctuates in response to short-run variations in supply and demand. Considering it in their own interest then to have a stable price, they take the price they set as given for the time being and decide the amount of copper they will supply at that price. When the LME price is above the US price, producers do not increase the price for two reasons:

-Customers who can use aluminum, the main copper substitute, can invest in aluminum-use machinery and then they will not switch back to copper for a long time.[7]

-Higher prices might be a signal of higher long-run prices and then new producers will enter (either new mines will enter or existing mines will expand capacity).

To explain consumers' behavior, who take the U.S. price as given but also have the option of buying imported copper at the LME, the argument is that it might be profitable to buy domestic copper even when the U.S. producer price is higher than the LME price, because that will guarantee access to U.S. copper during future periods of disequilibrium (in case of rationing, for example).

[7] Vial(1988) considers that the main reason to keep stable prices was "the need to build consumers' loyalty in the face of the threat of further loss of the market to aluminum, which had a lower and more stable price than copper".

Some alternative and complementary explanations have been provided by Lal (1992) and Taylor(1978). Lal thinks that export quotas in the U.S.[8] and other countries permitted the separation of the U.S. from the world copper market. This segregation gave firms monopoly power and the existence of no resale clauses in the contracts prevented arbitrage from occurring. Taylor uses a model of vertically integrated firms, where production plans must be made prior to the knowledge of price, to show that price smoothing increase the expected profits of the firms overtime. This is due to a smoothing of production flows and the increased price information available to the firms. An additional incentive for smoothing price would exist if firms have a preference for a stable profit flow overtime.

It is important to mention that some few authors acknowledge the existence of the two-price system, but think that it had no effect on the competitiveness of the U.S. refined copper market. Richard (op. cit.), for example, considers that "the U.S. copper producers form a relatively weak oligopoly" and that "arbitrage between the U.S. price system and LME prices keeps the two prices in line with one another". The main reason for this to occur is that the U.S. secondary industry trades (mainly scrap) at LME prices and that assures the working of the arbitrage.

Independently of the reasons why the two-price system existed and if the U.S. producer price was a competitive one or not, it is a fact that the system ended during the late 70's. During early 70's the four largest copper-exporting countries (Chile, Peru, Zaire (Republic of Congo) and Zambia) nationalized their copper mines, which were owned mainly by American

[8] During the Vietnam war period quotas on exports of copper products were imposed. They started in november, 1965, and were dropped in early 1970.

multinational corporations. Chile, then, in 1976, decided to replace the U.S. producer price by the LME price as a reference for its exports and it was followed by others.[9] During these years also, several oil companies (Exxon, Amoco, BP, and Royal Dutch Shell) started buying mining companies.[10] As a result, by mid 70's U.S. copper multinationals had lost a large fraction of their market share to large state-owned companies based in poor or developing countries and to oil multinational companies. Furthermore, for the first time, the U.S. was a net copper importer.[11] In 1978, the largest U.S. producers[12] began using the Comex price of refined copper as a benchmark for setting their prices. Since Comex and LME prices are closely linked by arbitrage, the two-tier price system came effectively to its end.[13]

3 The Copper Market

3.1 Copper Demand Function

Copper is mainly an input to produce durable goods and, therefore, the demand for copper is a derived demand. Immediate consumers of copper are mainly semi-fabricators (rod mills

[9] In 1977, Peru, Zaire and Zambia tried to increased copper prices by setting export quotas for the four largest copper-exporting countries. The attempt failed when Chile refused to accept quotas because it was involved in a process of expanding capacity.

[10] According to the Office of Technology Assesment of the U.S. Congress (1988), in 1983, mines owned by oil companies represented 10% of the total production from the world's 50 largest mines.

[11] In 1978 the industry filed a petition for imports relief with the ITC, which recommended to imposed a quota on copper imports, but President Carter rejected it.

[12] In may 1978, Kennecot, the largest U.S. domestic producer, announced that it would start using Comex prices as a reference for its contracts.

[13] Vial (op.cit.) also considers as an important explanation of the switch to Comex price the new situation in the aluminum market. In the late seventies the price of aluminum become more volatile due to increasing competition in the market, and due to the increase in the cost of converting bauxite into aluminum as a consequence of higher energy prices. With a higher and less stable aluminum prices, the threat of consumers switching to aluminum was dramatically reduced and, therefore, the need of stable copper prices to build consumer loyalty disappeared.

and brass mills) that use copper to produce intermediate goods that are then used as inputs by the end users of copper[14]. The main industries using semi-fabricated copper goods as inputs in the U.S. are, based on the Copper Development Association reports, electric and electronic products (for telecommunications and wiring devices), building construction (for plumbing, heating, air conditioning, and wiring) and industrial machinery and equipment. The production of durable goods is highly energy intensive and the main copper substitute in these industries is aluminum. Using this information the following copper demand can be specified:

$$\begin{aligned} \log C_t &= \beta_0 + \beta_1 \log Pc_t + \beta_2 \log Pa_t + \beta_3 \log Pe_t + \beta_4 t + \\ &\quad \beta_5 \log w_t + \beta_6 \log IP \end{aligned} \tag{1}$$

where,

w_t : wage

Pc_t: price of copper

C_t : quantity of copper

Pa_t : price of aluminum

Pe_t : price of energy

IP_t: industrial production

[14] Wire mills produce bare wires, insulated wires and cables; and brass mills produce mainly shapes (sheets, rods and tubes). The two main uses of copper in the US economy are building construction (40%) and electrical products (20%).

Equation (1) is the demand function to be estimated in the empirical part.

3.2 Copper Supply

The technology and processes required to produced refined copper from copper ores found under the ground is quite simple. The production of refined copper involves four steps: mining, concentration, smelting and refining.

In the mining process, copper ores are extracted from the ground and crushed. During the concentration process crushed ores are treated either in a leaching or a concentration plant, where copper cements (precipitate) and concentrates are obtained respectively. Copper mines and treatment plants are always vertically integrated. The reason for this is the transportation cost; it is expensive to transport ores that contain less than 1% of copper on average[15].

In the smelting stage, copper cements and concentrates are processed in a smelter, where they are melted and oxidized in furnaces to remove impurities[16]. The final output of the smelting process is copper blister. Finally, in the refining stage, copper blister casted in the form of anodes is placed in tanks containing an electrolytic solution and sheets of electrolytic copper. Then, direct current is applied to the solution and the copper is dissolved from the anodes and deposited as refined copper in the cathodes. The final output is an electrolytic copper cathode (refined copper) with 99.9% purity, the final product for industrial consumption.

It is important to mention than during the refining stage some valuable by-products are

[15] It is expensive in the sense that you are paying to transport 99% of wasting material.

[16] If the leached solution is rich enough, copper oxides can be alternatively treated in a solvent extraction-electrowinning (SX-EW) plant whose final output is a copper cathode. With this process the smelting and refining stages are skipped, but some electrowon cathodes have less purity than electrolytic cathodes and they need to pass trough the refining stage anyway.

recovered. Obviously, these by-products do not change the cost of producing refined copper, but they must be considered because they make production more profitable. Usually the type of by-products obtained depends on the geographic region of the mine, but, in general, the most common copper by-products are gold, silver, nickel, zinc, molybdenum and cobalt[17].

The estimation of the copper supply in the literature has usually been done under the assumption of a partial adjustment model, which implies an increasing marginal cost function.[18] However, simulations and estimations done with a constant marginal cost up to capacity have performed much better when compared with actual cost data. Hartman, Bozdogan and Nadkarni (1979), for example, use engineering estimates of the variable factor inputs to estimate the pollution abatement compliance costs of the copper industry. Historical simulations for production and extensive cost analysis validate the model. Foley and Clarke (1982) derive supply schedules from site- and input-specific cost data from 47 copper operations in the U.S. and they conclude that "unit operating costs are constant up to maximum capacity".[19] Furthermore, people within the industry consider that a constant marginal cost is what best approximates their costs[20]. Hence, I will assume a production function with constant returns to scale, which

[17] Copper ores in South Africa and Philipines are rich in gold; in Chile and the U.S. they are rich in silver; in Zaire and Zambia they are very rich in cobalt; and, in Canada they are rich in nickel and zinc.

[18] Except Vial (1988) who estimates a constant marginal cost function and to validate that specification he estimates a Cobb-Douglas production function allowing non-constant returns to scale. The empirical results and hypothesis testing of the latter estimation do not reject the constant returns to scale property, implying a constant marginal cost.

[19] The additional evidence they provide to support this conclusion is that "In the short-run, copper mines and mills vary output by increasing the numbers of shifts worked per week, thus keeping marginal cost fairly constant. Inventory control of concentrate is used to keep daily smelter production at a reasonably steady level. When a serious oversupply or undersupply of concentrates exists in inventory, the mine or smelter is shut down for a short period".

[20] This comment is based on discussions with operating and management personnel of Enami, Codelco and NorDeutsche-Refinery, and several visits to their smelters and refineries.

allows me to specify a log-linear constant marginal cost:

$$\log MC_t = \alpha_0 + \alpha_1 \log w_t + \alpha_2 \log Ps_t + \alpha_3 \log Pe_t + \alpha_4 \log Pf_t + \alpha_5 t \tag{2}$$

where:

w : wages

Ps : price of silver

Pe : price of electricity

Pf : price of fuel oil

t : time trend

Under the assumption of joint-profit maximization the problem of the U.S. producers is:

$$\max_{p_t} \pi_t = Pc_t C_t - TC(C_t, w_t, Pe_t, Pf_t, e^{\mu t}) \tag{3}$$

The first order condition for this problem is:

$$C_t + \frac{\partial C_t}{\partial Pc_t} Pc_t - \frac{\partial TC(C_t, w_t, Pe_t, Pf_t, e^{\mu t})}{\partial C_t} \frac{\partial C_t}{\partial Pc_t} = 0 \tag{4}$$

which can be rewritten as:

$$Pc_t \left(1 + \frac{1}{\eta}\right) = MC_t \tag{5}$$

where η is the demand price-elasticity ($\beta_1$from equation (1))and MC_t is the marginal cost of the copper industry. As usual, the left hand-side of equation (5) is the monopoly marginal revenue, which would be equal to just Pc_t in a perfectly competitive model. Equation (5) then, describes the supply correspondence of a monopolist, which becomes a supply function in the case of perfect competition (when $\eta = -\infty$). If we want to also consider the broad range of oligopoly models that lay between the two extremes of perfect competition and monopoly, equation (5) can be modified as:

$$Pc_t \left(1 + \frac{\theta}{\eta}\right) = MC_t \tag{6}$$

where θ is a parameter measuring market conduct. Now, using equations (2) and (1) and taking logs, equation (6) becomes:

$$\log Pc_t = \alpha_0 + \alpha_1 \log w_t + \alpha_2 \log Ps_t + \alpha_3 \log Pe_t + \alpha_4 \log Pfo_t + \alpha_5 t - \log \left(1 + \frac{\theta}{\beta_1}\right) \tag{7}$$

Defining D_t as a dummy variable equal to one when the industry is under any cooperative regime and equal to zero when is perfectly competitive, a change in regime allows to identify θ,the parameter of interest. Using this new variable, equation (7) is modified to:

$$\log Pc_t = \alpha_0 + \alpha_1 \log w_t + \alpha_2 \log Ps_t + \alpha_3 \log Pe_t + \alpha_4 \log Pfo_t + \alpha_5 t + \alpha_6 D_t \tag{8}$$

Under any cooperative regime market prices should be higher than under perfect competition, and, therefore, α_6 should be positive but less or equal than $\log \left(1 + \frac{1}{\beta_1}\right)$.

As in Porter (1983), if the sequence $\{D_1, ..., D_T\}$ is known, equations (1) and (8) can be consistently estimated using two-stage least squares.

4 Data

The American Bureau of Metal Statistics publishes an annual yearbook that contains monthly prices, consumption, imports and exports data for most of the non-ferrous minerals. Even though the data are available for the whole period 1945-2000, I used monthly data only for the period 1950-1995. The main reason to start in 1950 and not in 1945 is that price controls imposed during World War II were removed in 1949. The reason to stop in 1995 is that the methodology used to calculate refined copper consumption was changed after that year and, therefore, the data are not comparable.[21]

Table 1 shows the summary statistics of the data. The variable used to measure consumption is deliveries of refined copper to fabricators in the U.S. and it measures recoverable copper content in tons of 2,000 pounds.[22] The copper price is the U.S. producer price for electrolytic copper in cents per pound. The price was not reported by producers between September 1967 and march 1968, and also on july 1971. Fuel Oil prices are the No. 2 fuel oil prices at New York in cents per gallon, as reported in Platt's Oil Price Handbook.. The price of electricity is an index of industrial electricity for 2,000 kwh. The problem with this variable is that is not available before 1958, which forces the estimation of the model using only data for the period 1958-95. As an alternative, I also estimate the model replacing the fuel oil and electricity prices by a price index for fuels and electricity from the Bureau of Labor Statistics that covers the whole period 1950-95. The variable I use for wages is the average hourly earnings

[21] I contacted the American Bureau of Metal Statistics to see if it was possible to construct a comparable series for consumption after 1995, but they claim they cannot obtain the data from the fabricators to do it.

[22] Authors who have estimated copper demands for periods before 1973 have used the variable "net consumption by fabricators", also published by the Bureau of Metal Statistics. This migth be a better measure of copper consumption but it was discontinued in December of 1973.

of production workers in primary metal industries. As a measure of activity or production levels in the semi-fabricated copper goods industry I use the Index of Industrial Production in Manufacturing.[23] All data are not seasonally adjusted and prices are deflated by the Producer Price Index for durable manufacturing (march 1999=100).

Table 1: Summary Statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
Copper Consumption	140434.6	31582.1	57505	238152	552
Real Copper Price	102.38	22.55	57.78	164.04	544
Real Aluminum Price	73.11	11.67	41.45	105.49	552
Real Fuel Oil Price	45.44	19.95	26.53	107.89	552
Real Electricity Price	81.59	17.19	58.44	114.28	456
Real Fuel-Power	57.894	15.86	39.92	101.90	552
Real Primary Metals Wage	10.07	1.17	7.31	11.87	552
Real Silver Price	542.95	350.67	293.6	3854.45	552
Ind. of Industrial Production	64.53	26.06	21.91	119.33	552
Strike 1959	0.0217	0.1459	0	1	552
Strike 1967-68	0.0181	0.1334	0	1	552
Strike 1983	0.0108	0.1037	0	1	552
Korea	0.043	0.2041	0	1	552
Vietnam	0.1847	0.3884	0	1	552
Time	276.5	159.49	1	552	552
Ration 1	0.038	0.1914	0	1	552
Ration 2	0.136	0.3429	0	1	552

Additionally, a set of dummy variables was constructed for strikes and wars: Strike83 is equal to one for the period july 1983 - November 1983; Strike6768 is equal to one for the period july 1967- april1968; Strike5960 is equal to one for the period august 1959 - February 1960; Korea is equal to one for the Korean war period (June 1950 - July 1953); and Vietnam is equal to 1 for the Vietnam War period (August 1964-January 1973).

Finally, it might be relevant for the empirical strategy that there is some anecdotal evidence

[23] I also considered the Index of Industrial Production for Durable Goods and the Total Index of Industrial Production, but the results were almost identical.

showing that U.S. producers rationed U.S. consumers in 1954-1956 and 1964-1970.[24] The variable Ration1 is equal to one for the period october 1954 - June 1956 and, Ration2 is equal to one for the period january 1964 - February 1970. The latter two periods were identified as periods of rationing by McNicol (1975) and as periods of excess demand by Mackinnon and Olewiler (op. cit.).[25]

5 Results

5.1 Demand

Table 2 shows the results of the two-stage least squares estimation of equation (1) using Prais-Winsten two-step procedure with AR(1). One of the potential issues to be considered is that if what the literature has reported is true about periods or rationing, then the demand function cannot be estimated for those periods unless efficient rationing was used. I deal with this potential problem in three ways. First I estimated the demand function assuming that efficient rationing was used (models 1 and 2 in table 2). Second, I estimated the demand function adding dummy variables and/or dummy variables interacted with copper prices for the rationing periods. The coefficients of these variables were never significant and the rest of the coefficients remained almost unchanged. And third, I dropped from the sample the observations for rationing periods (models 3 and 4 in table 2). The only difference between

[24] Most of the information regarding the rationing periods is anecdotal and the investigation of the Houthakker Committee provided little evidence concerning the timing and duration of rationing. There is no mention at all about which buyers were rationed, how allocations were determined and how resale was prevented.

[25] In the literature, the existence of rationing has been basicallly inferred comparing the difference between the refined copper price and the price of scrap with the conversion cost of scrap into refined copper. However, conversion costs are estimated with a regression using a sample that excludes the rationing periods.

models 1 and 2 and between 3 and 4 is that in the first-stage regression of models 2 and 4, the prices of electricity and fuel oil were replaced by the fuel and power price index, allowing the use of the observations for the period 1950-57.[26] The coefficient for the Vietnam dummy variable was very close to zero and never significant in any of the models, so I dropped it from the final specification.

Table 2: Demand

Copper Consumption	Model 1	Model 2	Model 3	Model 4
Copper Price	-0.3952	-0.3454	-0.4290	-0.3886
	(0.1405)	(0.1531)	(0.1333)	(0.1495)
Aluminum Price	0.0369	0.0352	0.0419	0.0544
	(0.0339)	(0.0600)	(0.0567)	(0.0565)
Ind. Indust. Prod.	1.4779	1.3108	1.700	1.4389
	(0.1552)	(0.1162)	(0.1306)	(0.1022)
Fuel Oil Price	-0.0738	-0.0933	-0.0928	-0.1162
	(0.0309)	(0.0318)	(0.0307)	(0.0304)
Quarter 1	0.0847	0.0689	0.0963	0.0860
	(0.0208)	(0.0186)	(0.0197)	(0.0180)
Quarter 2	0.0826	0.0782	0.0837	0.0798
	(0.0223)	(0.0210)	(0.0205)	(0.1851)
Quarter 3	-0.0552	-0.0617	-0.0500	-0.0522
	(0.0224)	(0.0199)	(0.0222)	(0.0191)
Time	-0.0033	-0.0029	-0.0040	-0.0033
	(0.0005)	(0.0003)	(0.0004)	(0.0003)
Korea		0.1609		0.1103
		(0.0427)		(0.0303)
Constant	8.9485	9.3163	8.6500	9.2484
	(0.9831)	(1.1725)	(0.8194)	(1.0280)
Adj. R^2	0.9033	0.8868	0.9119	0.92
N	417	513	349	424
F	498.52	454.46	449.18	532.42

Numbers in parenthesis are standard errors.

The copper price is lagged eleven periods to be consistent with the one-year contracts between producers and consumers, reflecting then the average time that fabricators need to

[26] Recall that the price of electricity is available since 1958.

adjust their production decisions when copper prices change.[27] The use of lagged prices might imply that there is no endogeneity of prices, but as stated by McKinnon et al. (op. cit.) "U.S. producers know that copper demand depends on lagged prices and they will take future developments on the demand side into account when setting producer prices". For this reason, and following almost everybody in the literature, I preferred the use of instrumental variables. As can be seen in the next section, I use the real wages of production workers in primary metal industries and the real price of silver as instruments. The estimated copper price elasticities are negative and significant, ranging between -0.35 and -0.43. Table 3 shows a summary of the price elasticities estimated by other authors in the literature, using different data frequency and periods. As can be seen when comparing to table 2, the results are in the upper range of what other researchers have found.

Table 3: Demand Elasticities

Author	Data Frequency	Period	Elasticity
Bozdogan and Hartman (1979)	annual	1950-73	-0.47
Charles River Associates (1970)	annual	1950-67	-0.21
Fisher, Cootner and Baily (1972)	annual	1950-66	-0.213
Labys (1989)	annual	1971-85	-0.39
Mackinnon and Olewiler (1986)	quarterly	1947-74	-0.42
McNicol (1975)	annual	1949-66	-0.326
Taylor (1979)	quarterly	1956-75	-0.2
Thurman (1988)	monthly	1975-84	-0.27
Vial (1988)	annual	1965-84	-0.188
Wagenhals (1984)	annual	1950-80	-0.35

The main purpose of this paper is to estimate market power, and, one of the key parameters for doing it, is the price elasticity. Hence, an estimated coefficient that is inconsistent or biased

[27] This is an unanimous practice in the literature. Authors using annual data lag prices one year and authors using quarterly data lag prices three quarters.

would lead us to wrong conclusions about the market conduct of the industry. In this sense, it is important and reassuring to see that the estimated elasticities are within the range of what others have estimated. Still, there is another potential problem that must be addressed, which is the stability of the coefficient. I am estimating a demand function for a period of 45 years, and it is reasonable to think that the price elasticity might have changed. I explored this possibility in two ways. First, I divided the sample in two periods, before and after 1978, and estimated the four different models for each sample. Then, I used a Chow test to test for the stability of the price elasticity in each model. In all cases the test does not reject the hypothesis of stability of the coefficients.[28] Secondly, I estimated the four models including a dummy variable interacted with the copper price. Initially, I set the dummy variable to be one before June of 1978, and zero otherwise, but I also explored some other possibilities. In all cases, to my own surprise, the coefficient of the dummy variable interacted with copper prices was close to zero and not significant.[29]

Following what many authors have done in the literature, I used the aluminum price lagged 11 periods. The reason for this is to reflect the fact that fabricators cannot switch from copper to aluminum instantly, they require to make some adjustment in the production process and to invest in some new equipment, and to do this takes time (at least one year seems to be the consensus in the empirical literature). The coefficient of the aluminum price was positive as expected for a substitute good, but not significant. Several authors have reported a similar result or even a negative coefficient. The main explanation found in the literature, is that

[28] Vial (1989) also performed several Chow and Cusum tests, and the null hypothesis of stable coefficients was never rejected.

[29] In Model 1, for example, the coefficient was -0.001 with a standar error of 0.023.

the aluminum is not an equilibrium price but, as stated by Fisher (op. cit.), "an unrealistic quotation which is either widely discounted or produces severe rationing on other occasions". The most common solution, at least when using annual data, has been to use aluminum prices in Germany, a competitive market. There are no monthly data available of aluminum prices in Germany, so I could not implement that solution and I decided to keep the variable in the regression even if it was not significant.

The coefficient of the Index of Industrial Production (IIP) was positive, as expected, significant, and it ranged between 1.5 and 1.7. Based on the main industries using copper in the U.S., I also estimated the models using the IIP for Durable Goods and the Total IIP, but the results were not very sensitive to the index chosen. I decided then to report the results using the IIP for Manufacturing because the R^2 was slightly higher.

The estimated coefficient of the Fuel Oil price has the expected sign, ranges between -0.07 and -0.11, and is significant. Even though the fabrication of durable goods is very intensive in the use of energy, especially fuels, many researchers have failed to consider an energy variable in the specification of the copper demand. Vial (1989, 1991) is the only one I am aware of who has included an energy variable, and he reports a range of elasticities between -0.06 and -0.15, with a mean of -0.0906. These numbers are consistent with the fuel oil elasticities estimated by the four models in table 2.

The time trend is negative and significant. I did not have an expected sign for this variable, but Vial (1991) shows that there is a decreasing trend in the long-run evolution of the intensity of use of copper, which might be explained by the replacement of copper by fiber optic in the electronic industry and plastic in the construction industry. The quarterly dummies were also significant, showing a negative seasonal effect during the third quarter. The dummy for the Korean war was positive and significant, showing a shift in the demand curve that reflects the increase in demand due to the war.

Finally, it is important to mention that some authors have argued that the change in inventories of fabricated copper products affects copper consumption and, therefore, it should be included in the estimation of a refined copper demand. There is no public information on total inventories of the fabricators, so, as a proxy, I used the change of total inventories of durable goods in manufacturing industries. The coefficient was never significant and the other coefficients were unaffected.

5.2 Supply Correspondence

As it was mentioned in Section 3.2, equation (8) can be consistently estimated if the sequence $\{D_1, ..., D_T\}$ is known. Since the identification of θ comes from the shift in regime, from cooperative to competitive, it is critical to use the correct sequence. There is a generalized consensus in the literature, the specialized magazines and managers of copper companies I talked to, that the U.S. copper industry is a very competitive one since 1980 at least. This allows me to set the sequence $\{D_{january1980}, ..., D_{december1995}\}$ equal to zero. On the other hand, there is the same generalized consensus about the U.S. producers having some degree of monopoly power before 1978, allowing me to set the sequence $\{D_{january1950}, ..., D_{april1978}\}$ equal to one. The problematic period is between May 1978 and December 1979. As I mentioned in the introduction, in May of 1978, Kennecot, the largest U.S. domestic producer, announced that it would start using Comex prices as a reference for its contracts. Anaconda, another big producer, followed suit in August, just three months later. Some other producers switched to Comex in March of 1979 and the last ones did it in August of 1979. It is difficult to asses the degree of competition in the industry during this period, it is clearly a transition period and different hypotheses would imply different values for the sequence $\{D_{may1978}, ..., D_{december1979}\}$. Therefore, instead of guessing the right values for the sequence, I decided to drop the period of the sample. There are many alternative sequences that can be considered as opposed to simply dropping these observations, but I could not find any information that allows me to do an educated and accurate guess for the values of the sequence during this transition period.[30]

Table 4 shows the results of the estimation of equation (8). The coefficient of real wages is positive as expected, it ranges between 0.31 and 0.49 and it is statistically significant in all models.

The price of silver is negative and significant, with an elasticity that ranges between -0.075 and -0.093. It is true that this elasticity seems to be quite low, but it is statistically different from zero and that shows the importance of considering the copper by-products in the supply of copper. Authors describing the copper industry, its physical characteristics and its technology have been aware of this (Budge (op. cit.), Mikesell (1979), Wangehals (op. cit.)), but the empirical work has usually disregarded the role of copper by-products.

The coefficients of Fuel Oil and Electricity prices were both positive and significant; they range between 0.04 and 0.043 for fuel oil and between 0.52 and 0.56 for electricity. The elasticity of electricity is more than ten times higher, in absolute value, than the elasticity of fuel oil,

[30] I explored three alternatives: first, I set the whole sequence equal to one; second, I set the whole sequence equal to zero; and third, I set the first half equal to one and the second half equal to zero. The results did not change dramatically and the conclusions regarding θ were not affected.

which might reflect that the electricity used in the refinery is a more important input than the fuel oil used in the smelter.[31] When the index of energy prices is used instead of fuel oil and electricity, the results do not change much. The estimated elasticity of the energy price is 0.35 and is also statistically significant.

Table 4: Supply Correspondence

Copper Price	Model 1	Model 2	Model 3	Model 4
Real Wage	0.3360	0.4534	0.3099	0.4930
	(0.1544)	(0.1536)	(0.1572)	(0.1551)
Price of Silver	-0.0797	-0.0922	-0.0749	-0.0933
	(0.0272)	(0.0260)	(0.0299)	(0.0279)
Price of Fuel Oil	0.0399		0.0431	
	(0.0276)		(0.0281)	
Price of Electricity	0.5177		0.5651	
	(0.1372)		(0.1502)	
Price of Energy		0.3451		0.3586
		(0.0865)		(0.0914)
Strike80	0.0307	0.0219	0.0291	0.0286
	(0.0411)	(0.0401)	(0.0446)	(0.0428)
Strike6768	-0.0062	-0.0043		
	(0.0288)	(0.0278)		
Strike59	0.0070	0.0085	0.0070	0.0082
	(0.0291)	(0.0281)	(0.0315)	(0.2998)
Time	0.0005	0.0002	0.0004	0.0003
	(0.0004)	(0.0003)	(0.0006)	(0.0005)
D	0.2907	0.3172	0.2774	0.3124
	(0.1185)	(0.1102)	(0.1147)	(0.1114)
Constant	6.0376	5.4416	6.1639	5.6412
	(0.8242)	(0.6399)	(0.9039)	(0.6725)
θ	0.0996	0.0938	0.1039	0.1042
R^2	0.8866	0.8532	0.9022	0.9099
N	429	525	361	436
F	246.62	226.25	263.69	351.65

Numbers in parenthesis are standard errors.

The strike dummies were never significant. This is not what I expected, but I think is not

[31] The total estimated energy requirements are around 9 million Btu per ton of copper cathod produced in the smelting process (roughly 2/3 in fuel and 1/3 in electricity) and around 6 in the refining stage (all in electricity).

surprising because they represent very short-periods of time with respect to the whole sample. The time trend is positive and not significant. This variable should capture the technological progress in the production of copper. A very small coefficient like the one estimated, shows how slow and gradual the technology of producing copper has evolved.[32]

The coefficient of the D dummy was positive, significant, and it ranges between 0.28 and 0.32. This coefficient is α_6 in equation (8), which represents the difference in the intercept of the supply relationship between the cooperative period (before 1978) and the non-cooperative one (after 1978). Under the assumption that $\alpha_6 = -\log\left(1 + \frac{\theta}{\beta_1}\right)$, the value of θ implied by the estimated coefficients of α_6 and $\beta_1$ranges between 0.09 and 0.1. These estimates of θ are significantly different from zero, which represents a deviation from perfect competition ($\theta = 0$), but such low values of the estimates are basically consistent with prices close to the ones predicted by a competitive model of the industry. Although the result might be surprising, given all the anecdotal evidence on the contrary, it is also important to recall that the value of θ must be interpreted only as the average market conduct of the industry for the period. Therefore, what the empirical results show is that during the period 1950-78 copper prices, on average, were quite close to competitive prices.

It could be argued that the results are also consistent with a symmetric Cournot behavior in the case of ten firms ($\theta = 0.1$). However, as it was mentioned at the beginning, during most of the period there were only three major producers and if the "custom smelters" are

[32] There is not much information available about the technological changes in the copper industry or the research and development efforts. In 1986, R&D spending of the U.S. copper industry was less than 1% of total sales and the national industrial average was 3.5% (U.S. Congress (op. cit.)). The same report states that "there have been no truly radical technological advances in mining technology for at least several decades".

also included, there were only five major firms in the market (which would imply $\theta = 0.33$ and $\theta = 0.2$ respectively).

It is possible that some firms decided to switch to LME prices because the market was already competitive. In that case the zeros in the sequence $\{D_1, ..., D_T\}$ should start quite before may of 1978, the exact month when the switch in regime occurred. I explored this possibility assuming that the industry had became competitive either one or two years before may of 1978. For this purpose I estimated equations (1) and (8) again using two different assumptions for the sequence $\{D_1, ..., D_T\}$. First, I set the sequence equal to zero after may of 1977 and, second, I set it equal to zero after may of 1976. The results were very similar and the hypotheses that either α_6 or β_1 are equal to the previous estimates are not rejected.

It is also relevant to mention that the coefficient for α_6 is estimated quite precisely, the confidence intervals are between $(0.052, 0.502)$ and $(0.101, 0.533)$. If the lower value of the lower bounds (0.052) and the higher value of the upper bounds (0.533) of these intervals are considered as actual estimates of α_6, then the estimated θ would range between 0.022 and 0.142. This range still represents low market power and even the highest value (0.14) is less than symmetric Cournot with five firms. If the same exercise is done using the lower and higher values of the lower and upper bounds of the confidence intervals of both α_6 and β_1 for each model, then the estimated θ would range between 0.0023 and 0.281. Hence, only in the extreme case in which the actual estimates of α_6 and β_1 were both equal to the upper bound of their respective confidence intervals, the average market power would be close to a symmetric Cournot behavior.

The estimation of θ relies on the use of the correct functional forms of the supply and demand function and, therefore, it is important to consider how sensitive the results are to a different specification. For this purpose I estimated equations (1) and (8) using a linear specification. The estimated demand elasticities were lower than the ones estimated using a log-linear specification, ranging now between -0.1164 and -0.2371. The estimated θ ranged between 0.0022 and 0.0091, and it was not significant in two cases and significant at 10% in the other two.[33] The conclusions from these results are not dramatically different than the ones using a log-linear specification, even though they are stronger in terms of not finding market power. The estimated θ is even smaller and in most of the cases statistically not different from zero, which means that prices in the copper industry during the period 1950-1978 were, on average, not significantly different than the ones predicted by a competitive model of the industry.

Finally, in light of the empirical results, I would like to revisit the existence of rationing in the U.S. copper industry during this period. There are two main attempts in the literature trying to explain why copper producers might have rationed consumers. McNicol (op. cit.) identifies two circumstances in which rationing may be profitable for a copper producer. First, he shows that rationing may be a profitable response to a large, unanticipated increase in demand if there is long-run substitution in demand. Second, he shows that a partially integrated copper producer may find rationing profitable as means of partially achieving the effects of price discrimination. Following this latter argument, Lal (op. cit.) shows that if price discrimination is illegal, a monopolist maximizing long-run profits may not satisfy the demand of all consumers if consumers can be distinguished on the basis of stationary and non-stationary

[33] The results are shown in the appendix.

demand curves.[34] However, all these explanations are built on the assumption that copper producers had market power, assumption that is somewhat contradictory with the empirical findings of this paper.

The empirical results then, leave an open question: why would producers in an industry that charges prices close to marginal costs decide to ration consumers? There are three potential explanations. The first and simplest one is that rationing actually did not occur. There is mainly anecdotal evidence about the actual occurrence of rationing and the investigations of the Congress and the Department of Commerce were not conclusive on this regard, so this is a possibility that cannot be ruled out. A second one is related to the existence of some speculative bubbles in many commodity markets during the early 70s. These bubbles were motivated by fears of running out of natural resources and producers reacted trying to keep prices down because high prices could reduced future demand dramatically. A third explanation can be provided using a limit pricing model with capacity constraints. Slade (1991) shows that in a two-stage game where first-period prices affect demand in the second period, producers set low prices to discourage demand substitution (and/or entry) and ration consumers in periods of unexpected high demand. One of the interesting aspects of this model is that the strategic pricing (to avoid entry and/or demand substitution) and non-price rationing behavior is not effective without the joint action of the firms. Vives (1986) shows that in a market with concave downward sloping demand and symmetric firms which compete in prices with constant

[34] He considers two groups of consumers, one facing capital adjustment costs and one not. Consumers incurring capital adjustment costs have a demand for copper that is non-stationary (shost-run and long-run demand elasticities differ) and, therefore, copper producers can influence the investment decisions of these consumers through their choice of the copper price.

marginal costs and capacity limits, the symmetric mixed strategy Nash equilibrium converge to the unique competitive price provided that the unsatisfied demand is allocated according to what he calls "the surplus maximizing rationing rule" (efficient rationing).[35] Which of these three explanations better explains the U.S. copper industry is an empirical question that is beyond the scope of this paper.

6 Conclusions

Before 1978, most of the U.S. domestic copper production and an important fraction of the imports of refined copper were traded at a price known as the U.S. producer price, which was set by the major U.S. producers. At the same time, the rest of the world was trading copper at prices determined in auction markets like the London Metal Exchange (LME). It is a fact that this two-price system existed until 1978 and an important effort in the literature, has been devoted to show that the U.S. copper industry enjoyed monopoly power before 1978 and explain why that was the case. Less work has been done trying to test if that monopoly power was actually exercised or not and up to what extent. This paper tests empirically the competitive behavior of the US copper industry. The U.S. copper industry can be characterized as an industry with few sellers, important sunk costs, inelastic demand, and stable technologies. Consequently, and given all the anecdotal evidence, this is a type of industry in which one would expect to find evidence of market power. Surprisingly, the results are consistent with prices close to the ones predicted by a competitive model of the industry. However, it is important to

[35] Allen and Hellwig (1984) had previously shown that if proportional rationing is used instead, Nash equilibria still converge to a competitive price, but monopoly prices persist in some firms.

consider that these results must be interpreted only as the average market conduct during the period 1950-78. It is still possible that the industry had exercised some market power during very short intervals of time within this period and used a strategy of limit pricing to keep prices down on periods of high demand in order to discourage new entrants.

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Appendix

Table 5: Demand with Linear Specification

	Model 1	Model 2	Model 3	Model 4
Copper Price	-157.4484	-143.3011	-320.8634	-276.8073
	(72.8684)	(61.8425)	(68.3383)	(63.9805)
Aluminum Price	270.3848	192.8622	319.5924	230.1697
	(172.4344)	(127.5689)	(195.4523)	(138.7923)
Ind. Indust. Prod.	3446.511	3317.381	3756.553	3389.336
	(465.8608)	(393.7257)	(428.6542)	(378.9182)
Fuel Oil Price	-65.7127	-90.8249	-105.0055	-89.8765
	(25.668)	(19.2726)	(21.2096)	(20.6976)
Quarter 1	11857.42	9355.38	13536.45	10448.22
	(2971.372)	(2716.925)	(2929.107)	(2689.302)
Quarter 2	11477.60	10007.0	13257.84	10363.9
	(3392.364)	(2781.557)	(3069.796)	(2721.633)
Quarter 3	-7150.559	-7751.658	-5775.73	-6575.824
	(2951.885)	(2551.138)	(2819.162)	(2535.176)
Time	-490.7238	-394.011	-552.6691	-419.3821
	(91.1417)	(70.4039)	(82.2448)	(71.1551)
Korea		5247.249		5439.522
		(4847)		(5240.334)
Constant	77611.75	36674.31	90793.73	57065.58
	(25907.43)	(24448.24)	(21843.34)	(23443.37)
$\bar{R}^2$	0.3232	0.3425	0.4096	0.4230
N	417	513	349	424
F	21.38	25.95	24.98	28.37

Numbers in parenthesis are standard errors.

Table 6: Supply Correspondence with Linear Specification

	Model 1	Model 2	Model 3	Model 4
Real Wage	2.9152	4.0736	2.9177	4.0252
	(1.6481)	(1.7115)	(1.7272)	(1.8198)
Price of Silver	-0.0083	-0.0090	-0.0073	-0.0086
	(0.0031)	(0.0021)	(0.0030)	(0.0022)
Price of Fuel Oil	0.0671		0.1043	
	(0.0615)		(0.0579)	
Price of Electricity	0.5346		0.7075	
	(0.1465)		(0.1702)	
Price of Energy		0.4449		0.5014
		(0.1603)		(0.1277)
Strike80	0.5906	1.0912	0.2047	0.7712
	(2.9660)	(2.9484)	(3.2405)	(3.0738)
Strike6768	0.1966	0.9990		
	(2.9247)	(2.9122)		
Strike59	0.4078	0.7604	0.3676	0.7065
	(2.9373)	(2.9287)	(3.1898)	(3.0406)
Time	-0.0373	-0.0229	-0.0286	-0.0227
	(0.0429)	(0.020)	(0.028)	(0.013)
Constant	167.179	158.763	165.464	162.099
	(23.150)	(20.7236)	(23.459)	(19.968)
θ	0.0023	0.0035	0.0091	0.0072
	(0.0022)	(0.0038)	(0.0057)	(0.0043)
$\bar{R}^2$	0.3504	0.2779	0.4827	0.4475
N	429	525	361	436
F	17.01	14.98	26.67	28.21

Numbers in parenthesis are standard errors.