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THE GLOBAL SUPPLY CHAIN PRICING DYNAMICS

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ABSTRACT

Studying the intense price increases, followed by substantial price decreases, which occurred during the 2002-2009 years in the iron ore – steel – construction supply chain, one can see that the price oscillations follow a pattern similar to the physical ups and downs called the “Forrester – bullwhip effect”. The present paper suggests that there is a price system dynamics, parallel to the physical system dynamics. Its causes and consequences on economic crises are focused in the paper.

KEY WORDS

Supply Chain Pricing Dynamics; Bullwhip effect; ore-steel-construction SC

1. INTRODUCTION

The objective of this paper is to describe an economic phenomenon similar to the well known physical bullwhip – Forrester effect, studied since the fifties in System Dynamics Theory. Both effects, the physical and the economic one, take place in supply chains. This paper studies the economical bullwhip effect in the global supply chain of iron ore, steel and construction industry.

The iron ore, steel production, construction and house building industry constitutes an important supply chain, accounting for 20% of the GNP and employment in most countries. This paper studies the substantial price changes which affected the links of the chain in the 2002-2009 years. It was found that an increase in demand at the chain end (the demand side) triggered a housing price increase of 2 times in the USA home prices, of roughly 3 times in structural steel, 4 times in iron ore and 5 times in oceanic freight prices. When the home bubble bursted and the 2008 crisis prevailed, an opposite movement ensued: a strong plunge (50%) happened in home prices; a robust decrease (40%) in steel prices; and a relatively moderate decrease (30%) in iron ore prices.

Some causes of these ups and downs moves are very similar to the causes of physical oscillations occurrences in sales, production and inventories, characteristic of system dynamics. They are: delay in information concerning demand and price movements of the previous members of the supply chain; overreaction of members of the SC seeing an opportunity for price increase of their product without knowing fully how their increase will affect the cost structure of the whole SC.

The iron ore – steel – construction SC displays some characteristics which help to explain those large price swings. It is a highly value – added supply chain. At the start of this century, a tonne of good iron ore was worth US\$ 20; a ton of structural steel US\$ 300; a

tonne of automobile US\$ 20,000; a ton of weaponry US\$ 100,000; a tonne of robots US\$ 500,000. One could manufacture very valuable items with cheap steel associated to glass, rubber, plastics and component chips.

This is also true for most copper SCs, but not always for the aluminum SCs.

A second peculiarity is the fact that no real price increase occurred in the steel supply chain during five decades, from 1950 to 2000. Besides, this specific SC drew no public attention during half a century, because it was not related to new technologies. The real estate boom in the States and in China, coincidentally starting around 1995-2002, changed the landscape and acted as the third factor. Eventually a fourth factor played an important role. High grade quality iron ore (more than 63% metallic iron contained), without being a scarcity, is extracted in large amounts in two countries only: Australia and Brazil. Large scale exports are in the hands of three huge producers: BHP -Broken Hill Proprietary - Billiton, RTP – Rio Tinto Group, both in Australia; and Vale, formerly Cia. Vale do Rio Doce (CVRD), from Brazil. Producers of low grade iron ore, from 10% to 60% metal content, are USA, China, India, South Africa, Brazil and many other countries. Most modern blast furnaces – where iron is produced from iron ore – can only function efficiently with high grade iron ore. The trend is even to use increasingly pellets of iron ore, which are small balls of enriched iron ore, attaining a 70% metal concentration.

The factors listed above explain why the iron ore – steel – construction supply chain registered substantial price increases at the start of the century. It is drawing much attention, both when it boomed and when it receded, because it has something to do with the present economic crisis. It seems to be the ideal laboratory to study the price dynamics in a supply chain.

2. THE IRON ORE – STEEL – CONSTRUCTION SUPPLY CHAIN

Steel is an essential input in the construction industry and in numberless indispensable products: automobiles, trucks, buses, ships, trains, appliances, furniture, bridges, plants, weapons, machinery, tools, equipments of all kinds. Even when the building is made of concrete, steel rods, bars and beams are necessary to reinforce the structure. In metallic buildings, steel is the main component.

Figure 1 shows in a very simplified scheme the supply chain focused in this paper.

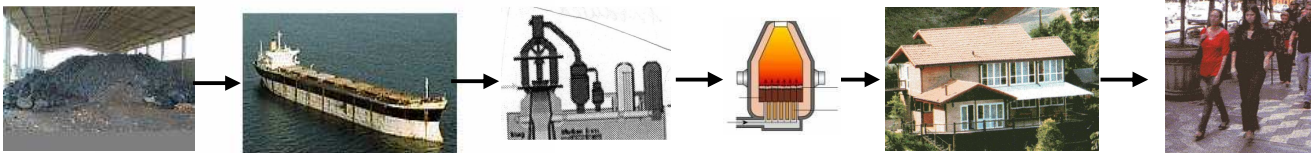


Figure 1

Simplified scheme of the iron ore – steel – construction supply chain

A more realistic – still very simplified – picture of the global iron ore – steel – construction supply chain is shown in Figure 2. It takes into account other raw materials, the fact that numerous countries produce steel and that there is a variety of countries to which steel is supplied, not only for construction, but for other uses also. It comes close to a network.

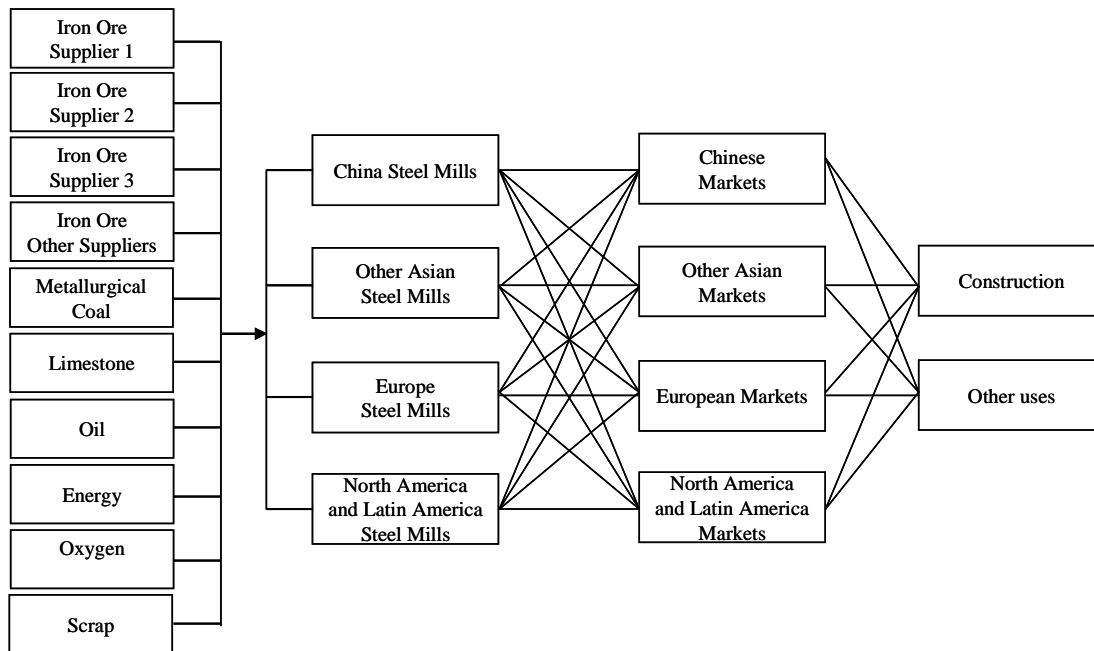


Figure 2

The iron – steel – construction network

3. COST AND PRICE STRUCTURES IN THE SUPPLY CHAIN

Iron ore mines area situated in the hinterland. The cost of mining, crushing the stone, sieving the powder, - upgrading the product, - shipping it to the railroad and hauling it to the nearby port amounts today to US\$ 15 per metric ton (also called tonne and equivalent to 1,000 kg).

Iron ore is sold in two configurations: lump, which is a pebblelike compound; and fines, which are dust. Fines can be sinterized, in shape of little ping-pong balls, called pellets.

Pellets and lump reach premium prices, but fines make up to 60% of the trade and are the price reference.

There are two markets for iron ore: one-year contract and spot. The contract price is negotiated yearly between the three large producers and the steel makers. The spot price is highly volatile, since it depends entirely on the mercurial market.

The pricing system is based upon the metal content. Iron ore is mostly ferric oxide Fe_2O_3 ; at the maximum purity level, the proportion of metal is 70%. Brazilian lump reaches a 67% purity level. But the referencial or benchmark price reported in statistics considers a 63% grade, fines, unless otherwise stated.

Ore prices are generally reported fob, which means free on board; in other words, the ore is delivered by the supplier at the port on the ship. Sometimes, mostly in the spot market, prices are stated cif, it is, including, besides the cost, insurance and freight. Under fob terms, in order to compute the cost of raw materials, one has to add the freight and insurance till the steel plant. In 2000-2002 the freight was some US\$ 10 per ton from Brazil to China.

Carbon steel used in construction of homes and offices is essentially the chemical element iron (Fe) plus a very small percentage (0.1%) of the element carbon (C). To obtain a ton of steel one requires, on paper, 2 tons of pure 70% iron ore (Fe_2O_3) and 0.160 tons of pure carbon. In practice, iron ore and coal carry impurities of many kinds. Much coal is burned in the reaction process aside the one used in the reaction itself. Half a ton of coal is many times consumed per ton of steel produced.

In the years 2000-2002, at the start of the boom which shattered the supply chain, the cost structure of steel produced in an integrated steel plant (one which makes steel by processing iron ore rather than using scrap) would look as follows (Table 1).

Table 1
Structure of “integrated” steel cost (long steel, bars)
(US\$ per ton)
2000-2002

Cost Components	Cost per ton US\$	Cost (%)	
		% of sale price	% of total cost
2 tons of iron ore	2 x 20 = 40	12.50	13.33
0.5 ton of coal	0.5 x 50 = 25	7.81	8.33
0.5 ton of limestone	0.5 x 10 = 5	1.56	1.67
Freights	2.5 x 20 = 50	15.63	16.67
Oil, oxygen, energy and other materials	20	6.25	6.67
Labour	20	6.25	6.67
Industrial charges	30	9.38	10.00
Overhead	10	3.13	3.33
Depreciation and Interest	100	31.25	33.33
Total cost	300	93.75	100.00
Gross Margin	20	6.25	
Sales price	320	100.00	

The fraction of the cost of steel in the construction industry is extremely variable, according to the nature of the building. It is assumed further to be 10% of the total cost.

4. COST AND PRICE CHANGES

The following chart (Table 2) shows the evolution of price of iron ore (fines), carbon steel (long products, used in construction) and real estate in USA. The period is 2000-2009.

Table 2

Price series for iron ore, steel and real estate

2000-2009

US\$

Year	Iron ore (US\$/ton)	Steel (US\$/ton)	Real estate Home Prices (2008 - US\$ inflation adjusted)
2000	27.6	300	175,000
2001	28.9	240	180,000
2002	28.6	300	190,000
2003	31.4	363	210,000
2004	37.3	750	225,000
2005	64.0	500	250,000
2006	76.2	640	275,000
2007	83.4	820	250,000
2008	132.2	1045	215,000
2009	90.6	690	-
2010 (estimates)	72.0	700	-

Sources: Iron ore: Advanced Explorations Inc. Current and Historical Prices

Steel: Worldsteelprices.com. World Carbon Steel Prices Structural Sections
and Beams

Real Estate: Home Prices U.S. Census. Annual U.S. Home Prices Median (\$)
Inflation adjusted

Figures are in US\$ per ton (not adjusted for inflation). The iron ore is shown in the contract mode for fines, fob, for the year contract, starting in April 1.

The steel price is quite difficult to establish, because there is an immense number of plants, in scores of countries, producing a large variety of products. By taking as homogeneous series of data, one obtains a constancy in the sequence of data, which is more important than the absolute values.

Real estate values were taken from the Annual U.S.Census and refer to U.S. Home Prices.

Considering the price peaks, we find the following results:

$$\text{Iron ore} \quad \frac{132.2}{27.6} = 4.8 \quad \text{peaking in 2008}$$

$$\text{Carbon Steel} \quad \frac{1045}{300} = 3.5 \quad \text{peaking in 2008}$$

$$\text{Home} \quad \frac{275,000}{175,000} = 1.6 \quad \text{peaking in 2006}$$

Figure 2 shows the yearly price changes. One can see clearly the time gaps between the price changes of the home prices, the steel prices and the iron ore prices, the first ones always preceding the last, according to the system dynamics findings.

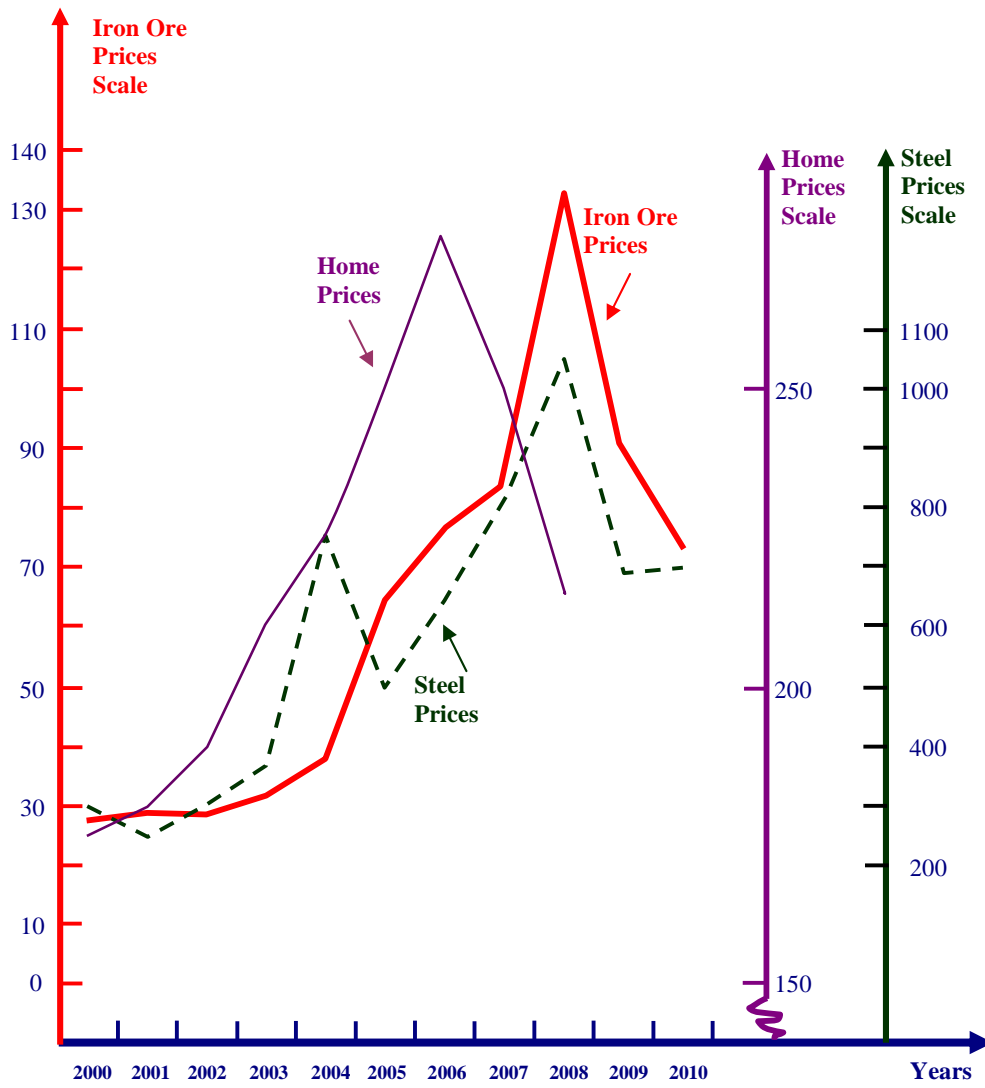


Figure 2

Price changes in the Supply Chain

Source: Table 2

5. INPUTS' COST AND PRICE INCREASES

By 2000-2002, the schematic price structure of carbon steel structural products was, per metric ton, in US\$:

Iron ore	40
Other costs	<u>260</u>
Total cost	300
Profit margin	<u>20</u>
Steel price	320

Note that the iron ore represents

$$p = \frac{40}{320} = 12.5\%$$

of the steel price

By 2008, assuming that the unique cost increase occurred in iron ore and was 300%, the new cost structure would be, in US\$ per ton:

Iron ore	160
Other costs	<u>260</u>
Total cost	420
Profit margin	<u>20</u>
Steel price	440

Observe that the iron ore

percent increase was:

$$a = \frac{160 - 40}{40} = 300\%$$

The increase in the steel price would be:

$$c = \frac{440 - 320}{320} = 37.5\% \text{ and } c = p.a = 12.5\% \times 300\% = 37.5\%$$

Assuming that the schematic price structure of construction, by 2000, was the following, per ton of steel used, in US\$:

Steel	320
Other costs	<u>2880</u>
Total cost	3200
Profit margin	<u>640</u>
Construction price	3840

Observe that the steel represents

$$q = \frac{320}{3840} = 8.33\%$$

of the construction price

By 2008, the construction price would be the follow:

Steel	440
Other costs	<u>2880</u>
Total cost	3320
Profit margin	<u>640</u>
Construction price	3960

The percent construction price increase is:

$$d = \frac{3960 - 3840}{3840} = \frac{120}{3840} = 3.125\%$$

Observe that $d = c q = p a q = 12.5\% \times 300\% \times 8.33\% = 3.125\%$

The formula - a multiplication of percentages - shows that the effect of a price increase in a raw material is diluted along the production chain in direct proportion to the raw material incidence on the product price.

Emulating the iron ore miners, the other inputs' suppliers – metallurgical coal, ocean freight, steel products – increased even more – fourfold, five fold – their prices, generating eventually a giant price increase in the chain, followed by a large – 50% off the peak – downfall.

6. FINAL CONSIDERATIONS

The similarities between price and physical bullwhip effects are considerable.

The physical bullwhip effect was first studied in vitro, by model building and simulations (Forrester, 1957), later reproduced in business games (Lee, 1997) and confirmed in real

cases (Chopra, 2001). Our price bullwhip effect was studied from data published in economic papers and official statistics (Advanced Explorations Inc., Worldsteel prices, U.S. Census). Delays in obtaining and processing information play the same role in both effects.

Price and cost figures are much more difficult to obtain than physical data, like production, shipments and inventories. There are many producers and a large variety of products.

Averages are not always reliable as a valid information. Also: are home prices an unbiased indicator of the construction industry?

More studies should be undertaken in this and other supply chains in order to verify the price effect found in this specific supply chain.

7. CONCLUSION

The worldwide price changes which occurred in the iron ore-steel-construction supply chain in the 2002-2009 period and might still be occurring in 2010 constitute a upheaval which reminds the physical “bullwhip effect”, identified in the fifties by Jay W. Forrester and other system dynamics pioneers. These price changes originated at the demand side of the supply chain – home building, mostly in USA and China – and propagated themselves as global waves reaching the steel makers and the iron ore miners. The causes and circumstances of these price increases, which were followed by price decreases when the housing bubble burst, are investigated in the paper. A single formula developed in the paper shows that cost increases in a raw material do not determine by themselves substantial price increases downwards in the supply chain. But all materials suppliers take advantage of this very fact to overreact to the boom in demand and overcharge the client, creating a reverse wave of price increases along the chain. The price system dynamics seems to run strictly in

parallel with the physical system dynamics effect. More chains must be studied to validate the results obtained in this specific supply chains.

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