# Changes in financial structure and industry product markets: an econometric analysis.

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**Abstract:** This paper presents a micro-econometric model testing for changes in firms' product and pricing decisions in two American industries where leading companies have sharply increased their financial leverage. According with the latest econometric theory, the empirical analysis is carried out through an *error-correction model* (ECM) which allows to separate the long-term from the short-term relationship between variables. The results from estimating show that the average industry debt ratio is a significant variable in determining product price level. In the first industry there is a positive correlation between debt and output; in the second industry output is negatively associated with the average industry debt ratio. Findings from the empirical analysis not only show the significance of debt's proportion in firms' financial structure, but also point out the importance of linking different effects of debt to specific scenarios (rivals' low financial leverage, low entry barriers, etc.).

**JEL Classification Numbers:** C32, C51, G32, L13, L7

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## Changes in financial structure and industry product markets: an econometric analysis.

### *1. Introduction.*

Modern economics has generated many theories of the ways in which a firm's financial condition may affect its conduct in the product market. In contrast with the majority of the past years' industrial organization studies, focused on the effects of production and pricing decisions on firm and industry profits, recent theoretical models by Brander and Lewis (1986), Maksimovic (1988), Gertner, Gibbons and Scharfstein (1988), Glazer (1989), Poitevin (1989), Bolton and Scharfstein (1990) and Phillips (1992) have formalized the ways in which industry product markets may both influence, and be influenced by, corporate financing decision. Yet, the latest theories on firms' value and valuation methods[1] point out the importance of taking into account the corporate financial structure, rather than "neutralizing" it, in the valuation process.

Although the economic literature has given rise to many theoretical models which have shown that output by a firm and its competitors can be affected by the use of increased debt financing, empirical evidence on this relationship is still at a starting phase.

Few empirical studies in the 70s appeared mostly as attempt of testing the original Modigliani-Miller hypothesis (whether investment and financing are treated by firms as separate decision) but they were not supported by a strong theoretical *a-priori* and a developed econometric thecnique as well. In the 80s, the lagged variables approach was introduced into the analysis[2]; however, the results of these more recent studies, (both the Ordinary Least Squared and the more sophisticated and statistically correct Two Stage Least Square) were difficult to interpret: although new debt issued appears as a significant explanatory variable with a positive sign in the investment equation, lagged debt appears with a significant negative sign.

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[1]T. Copeland, T. Koller, J. Murrin, "Valuation - Measuring and Managing the Value of Companies", (1994); R.A. Braley and S.C. Myers, "Principles of Corporate Finance" (1993).

[2]G. McCabe, *"The empirical relationship between investment and financing - A new look"*, Journal of Financial and Quantitative Analysis (1979) and P. Peterson and G. Benesh, *"A re-examination of the empirical relationship between investment and financing decision"*, Journal of Financial and Quantitative Analysis, (1983).

Only recently, following the qualitative approach adopted by the latest theoretical studies which focus on specific interactions between debt and firm's product strategies[3], very few articles by Borenstein and Rose (1995), Chevalier (1995), Kovenock and Phillips (1995) and Phillips (1995), which this work draws inspiration from, try to prove how the results predicted by the theory can be supported by what the actual oligopolies show.

This paper, through an econometric model, considers whether a firm's financial structure decision has an effect on its own *and* competitor's output and product pricing decision in two industries: the gypsum board and the high density polyethylene industries. These two industries lend themselves to investigation because they have limited numbers of producers and multiple firms that have sharply increased their debt financing; the largest firms have used leveraged recapitalisations to increase their debt ratios by more than 25 percentage points.

The empirical framework for examining the effects of capital structure on product markets is adapted from intra-industry industrial organization studies described in Bresnahan (1989)[4]. These studies of price and quantity decisions exploit the fact that price and quantity respond differently to exogenous demand shocks, depending on whether the industry is perfectly competitive.

By examining quantity and price data for each of these industries, we can try to see whether the industry output is *negatively* or *positively* correlated to the average industry debt ratio.

If there is *negative* correlation between industry output and debt ratio, the product price, in the estimated supply function, will be positively associated with the average industry debt ratio. This result is consistent with price increasing as output decreases, controlling for changes in input prices. If the industry data reflected this trend, we'd have a situation consistent with the group of theoretical models of capital structure and product-market competition (Glazer, Poitevin, Bolton-Scharfstein) that suggest product-market competition becomes "softer" when leverage increases.

Dealing with such a collusive effect of debt, a recent article on "*The Wall Street Journal*" shows how price/quantity agreements involved the polyethylene industry, in particular the same four leader firms which will be considered in this econometric test. It is interesting that the major producing firms, after a sharp increase of debt in the previous

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[3] The problem with this subject is the enormous complexity of the resulting model, which would make it impossible to obtain specific values for all variables in question.

[4] "*Empirical Studies of Industries with market Power*" (Chapter 17) Handbook of Industrial Organization, Vol II, (1989).

years, have taken a similar collusive conduct. The content of the article is reported in the footnote below[5].

In contrast with the situation described above, if the industry output is *positively* correlated to the average debt ratio in the same industry, we'll have a decrease in prices following an increase of debt level held by the firms. If we found this relationship as result of our empirical analysis, we could affirm that the actual strategic competition (our target oligopoly) can be better explained by those models (Brander-Lewis, Maksimovic) which predict that leverage changes managerial and shareholder incentives in a way that makes product-market competition "tougher".

The main difference with the analysis realized by Phillips[6] (1995), whose I adopt the criteria to identify the two selected industries, and with the few other empirical studies mentioned above, is the econometric model I use to estimate the interaction between capital structure and industry output decisions. Following the approaches of the latest econometric theory, demanding an economic explanation for the different signs of the parameters associated with each lagged variable, I estimate the two equations (supply and demand) through an *error-correction model* (ECM) which allows to separate the long-term from the short-term relationship between variables. In addition, the Dickey-

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[5] **FOUR POLYETHYLENE MAKERS FACE ANTITRUST INQUIRIES**

*Source:* The Wall Street Journal
*Date:* Friday Jan 27, 1995 Sec: A p: 12

*Abstract:*
Federal antitrust officials are investigating possible price fixing in the polyethylene business. The Justice Department has served at least four makers of the commodity plastic-**Dow Chemical Co**, **Union Carbide Co**, Chevron Corp's **Chevron Chemical** unit and Hanson PLC's **Quantum Chemical Corp**-with a 'civil investigative demand.'



*Article Text:*
PHILADELPHIA -- Federal antitrust officials are investigating possible price fixing in the polyethylene business.

The Justice Department has served at least four makers of the commodity plastic with a 'civil investigative demand.' Officials at the antitrust division of the department's Philadelphia office, which is said to be conducting the investigation, declined to comment.

A spokesman for Dow Chemical Co. said the company received the Justice Department demand this month based on allegations that 'manufacturers of polyethylene resins participated in an agreement in restraint of trade and price fixing.'

Dow, of Midland, Mich., said the demand 'ordered us to produce a wide range of documents and supply answers to a number of interrogatories' toaid the government in its investigation.

Quantum Chemical Corp., a unit of Hanson PLC; Union Carbide Co.; and Chevron Corp.'s Chevron Chemical unit said they have been contacted.

All denied violating antitrust laws, and said they were complying fully with the requests.

[6] In Phillips (1995) the parameters are estimated through a linear and static econometric model despite the explosive trend of the time series.

Fuller test, applied to the series and testing for trend-stationarity, seems to suggest itself this more sophisticated approach.

This paper proceeds as follows. Section 2 describes how industries have been selected, analyzes the data set and presents the gypsum and polyethylene industries. Section 3 provides a framework that shows how detailed price and quantity data can identify changes in industry product markets. The framework illustrates how industry product markets and output can be affected by capital structure. Section 4 presents the methodology used in specifying the econometric model and the estimation method. Section 5 illustrates the results of the product market and capital structure interaction tests for each industries. Section 6 concludes.

## 2. Data analysis and industries description.

### 2.1 Selection criteria and source of data.

In the two industries analyzed in this study - the gypsum and high density polyethylene industries - there have been large discrete increases in debt-to-value ratios. Firms in these industries have recapitalized using leveraged ricapitalizations and leveraged buyouts reducing retained earnings and free cash flow.

Since the purpose of this econometric test is measuring the level of consistency between the theoretical and empirical results, the first fundamental step is choosing an actual situation which follows as close as possible the basic hypothesis of the economic models. The two identified industries have been selected on the basis of four criteria[7]:

1) a discrete increase of at least 25% in debt-to-market value by the firm with the largest sales.
2) a limited number of producers in each industry, with the top four firms comprising at least 50% of the market.
3) product homogeneity within the industry.
4) the leading firm producing at least 50% of its sales in the same four-digit SIC code[8].

The sharp shift in capital structure increases the likelihood that any effect of capital structure on product markets can be identified. The second criterion increases the likelihood that price can actually deviate from marginal cost. As a matter of fact, Bertrand and Cournot models of competition, which the economic theory adopt to configure the strategic interaction among firms within the same industry, imply firms have enough market power to affect the market price and industry output level. In other words, it's important that the firms, in our target industries, are "price makers" and not "price takers". The third criterion improves the measurement of price data and reduces problems of differential product quality across firms. The fourth criterion decreases the possibility that the firm has different competitors for different products and thus increases the effect of industries firms' actions on each other.

Table 1 illustrates summary statistics[9] on the major firms and their rivals before and after the largest firms' recapitalizations.

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[7]The criteria follow those suggested by Phillips (1995).
[8]SIC stands for *Standard Industrial Classification*.
[9]Reported as in Phillips (1995).

*Table 1*:

| **Industry** | Changes in capital structure.<br>Three year % "debt/value". | Technology/<br>Barriers to entry. |
|---|---|---|
| *Gypsum board*<br>Leading firm: USG<br>2nd firm: National Gypsum | Pre-recap.= 35%; Post-recap.= 90%<br>LBO[11] in 1984 | Low MES[10].<br>Low fixed costs. |
| *Polyethylene high-density*<br>Leading firm: Quantum<br>2nd firm: Union Carbide | Pre-recap.= 36%; Post-recap.= 76%<br>Pre-recap.= 37%; Post-recap.= 55% | High MES.<br>Large fixed costs. |

"Pre-recap"[12] values are the means for three years prior to the leading firm's recapitalization announcement. "Post-recap" values are the means for three years after the recapitalization, or until the 1990 fiscal year-end. USG Corp.'s (US Gypsum Corp.) recapitalization was announced in 5/2/88 and completed in July 1988. Quantum Chemical Corp.'s recapitalization was announced in 12/27/88 and completed in January 1989.

Debt-to-market ratios are one-year pre- and post-recapitalization book value of debt divided by the book value of debt plus the market value of equity: $\frac{DT}{DT + MV}$, where *DT* stands for "debt-total" e *MV* for "market value".

Product market and capital structure interaction tests are conducted at the industry level using industry product price and quantity data. Industry price and quantity data were gathered for the primary product and the variable inputs in each of the two industries. The econometric model uses monthly time series from 1/1980 to 12/1990.

The variable inputs of the product were identified using the input-output tables of the Bureau of Labor Statistics. Most of the price data are from the *Producer Price Indexes* gathered by Bureau of Labor Statistics of US Department of Labor. All price data are deflated by the wholesale price index.

The general demand-shift variables for the two selected industries - industrial production, new constructions (residential and commercial), auto production - were obtained from the Federal Reserve Board's *Industrial Production* of US Department of Commerce.

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[10] Minimum efficient scale.
[11] Leveraged buy-out.
[12] "Pre-recap" = before recapitalization, "post-recap" = after recapitalization.

For the polyethylene industry, quantity data were provided by *Data Resources Institute* of McGraw-Hill (DRI/McGraw-Hill). For the gypsum wallboard industry, price and quantity series are from *Mineral Industry Surveys* of Bureau of Mines (US Department of the Interior).

Producing firms' market shares are identified by the respective individual firm segment sales, obtained from their annual reports. For the polyethylene industry, sales were not available and have been substituted by the individual firm capacity data obtained from the January annual issue of *Modern Plastics* (McGraw-Hill).

Finally, I gathered data on debt level held by the companies through COMPUSTAT[13] which allows the on-line access to the monthly up-to-dated database of Standard & Poor's. Among the many variation of debt ratios available in this database, (debt-total, debt in current liabilities, long-term debt, issuance of long-term debt, debts due in different years, etc.), only debt-total, short-term and long-term debt have been considered for the analysis.

The problem of converting, from annual to monthly, the time series of the average industry debt ratio, $\sum_{i=1}^{n} s_i \frac{DT_i}{DT_i + MV_i}$ (where $n$ is the number of firms in the industry; $s_i$ is the market share associated to the firm $i$), since debt ratios data are provided by firms annually (sometime semi-annually or, at most, quarterly), has been solved by dividing the debt annual series ($DT$) by the firm's market value monthly data ($MV$).

## 2.2 The gypsum wallboard industry.

Gypsum products are used primarily in the construction and home building market. The principal product in this industry is the gypsum wallboard.

Following the American "standard industrial classification", this product belongs to SIC code 3275[14] which I referred to for identifying the respective producer price index and average hourly wage.

[13]Provided by "The Fuqua School of Business" at Duke University.
[14]SIC Code:  3275 Gypsum Products
(from "*General Business File (Infotrac)"*, Fuqua School of Business Library).
*Dscription:*
Establishments primarily engaged in manufacturing plaster, plasterboard, and other products composed wholly or chiefly of gypsum, except articles of plaster of paris and papier-mache.

The gypsum industry has two principal firms that account for over 50% of the market: US Gypsum Corp. (USG) and National Gypsum Co. These two major companies are highly integrated in all stages of the production process. Following the two leader firms, USG and National Gypsum, which have respectively 20 and 18 industrial plants, Georgia-Pacific Corp. (10 plants), Domtar Co. (7 plants) and Celotex (4 plants) supply almost the remaining industry output; these five companies together produce 83% of the US national gypsum production.

A list of the major producers in the US gypsum industry is reported in the footnote below[15]; companies are sorted by sales value (in dollars), but revenues consider all the various lines of business (segment sales) which belong to the same SIC code (3275).

Both USG and NGCO[16] have had sharp changes in their capital structure. USG recapitalized using a leverage racapitaliztion, increasing its debt-to-market value by 50 percentage points in 1986. Differently, National Gypsum recapitalized using a leveraged buyout.

Graph 1 emphasizes the size of increasing debt level (issuance of debt[17]) in USG and NGCO capital structures, following the two recapitalizations occurred respectively in 1988 and 1986. Graph 1 illustrates the values, in millions of dollars, of debt issued by USG and NGCO during the decade 1980-1990.

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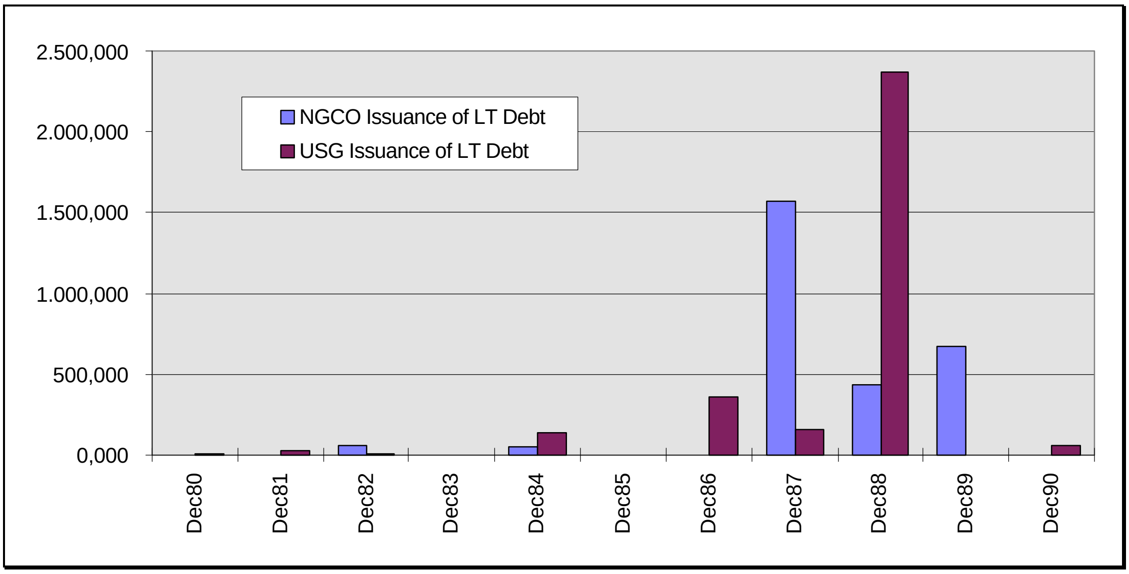
*Includes:*
Acoustical plaster, gypsum; Agricultural gypsum; **Board, gypsum**; **Building board**, **gypsum**; Cement, Keene's; Gypsum products: e.g., block, board, plaster, lath, rock, tile; Insulating plaster, gypsum; Orthopedic plaster, gypsum; Panels, plaster: gypsum; Plaster and plasterboard, gypsum; Plaster of paris; **Wallboard, gypsum.**

[15] **Georgia-Pacific Corp. Building Products Div.** Revenue: $5,923.0 M Sales, Employees: 6000. **Centex Corp.** Revenue: $3,277.5 M Operating revenue, Employees: 6000. **USG Corp.** Revenue: $2,290.0 M Sales, Employees: 12300. [a]**United States Gypsum Co.** Revenue: $1,400.0 M Sales, Employees: 10000. **National Gypsum Co.** Revenue: $630.5 M Sales, Employees: 2581. [b]**Gold Bond Building Products Div.** Revenue: $571.0 M Sales, Employees: 4000. [a]**USG Interiors Inc.** Revenue: $510.0 M Sales, Employees: 2500. **Celotex Corp.** Revenue: $190.0 M Sales, Employees: 2700. ("a" means that the company is controlled by USG; "b" means it's controlled by NGCO).

[16]From now on each company will be identified by its tiker simbol: NGCO = National Gypsum Co. GP = Georgia-Pacific, DTC = Domtar.

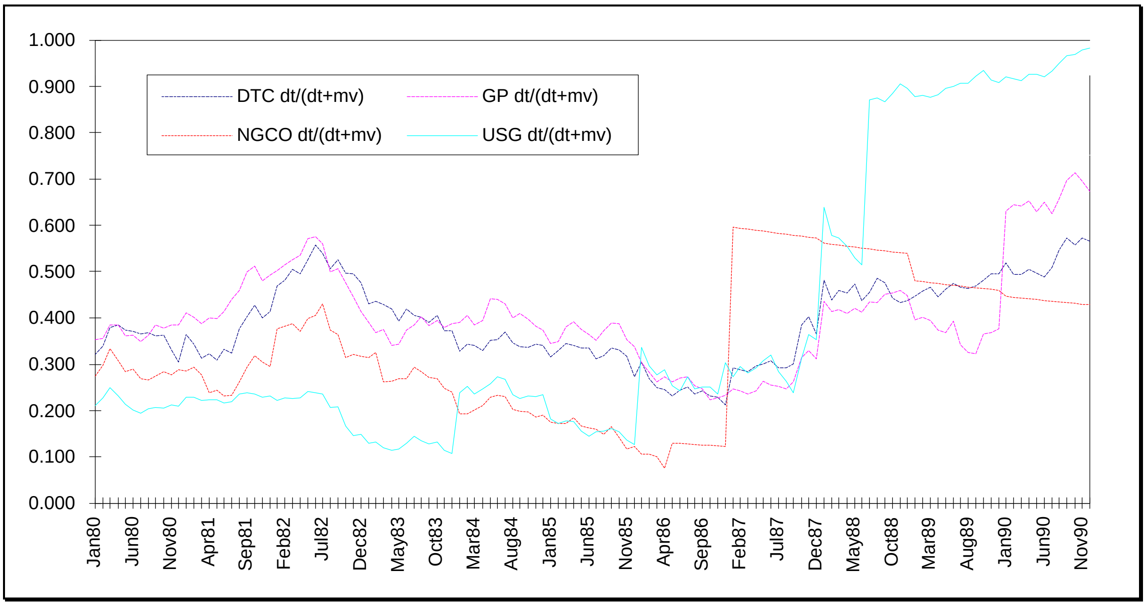
[17]"*Issuance of long-term debt"* represents the amount of funds generated from issuance of long-term debt. This item includes: increase in long-term and short-term debt when combined; long-term debt issued for or assumed for an acquisition; proceeds from bonds, capitalized lease obligations, or note obligations; reclassification of current debt to long-term debt.

*Graph 1:* Issuance of debt by NGCO and USG (millions of dollars).




Graph 2 considers long-term debt and short-term debt relative to firms' market value (monthly series).

*Graph 2:* Variations in debt-to-market value ratio, DT/(DT+MV), for the major firms.



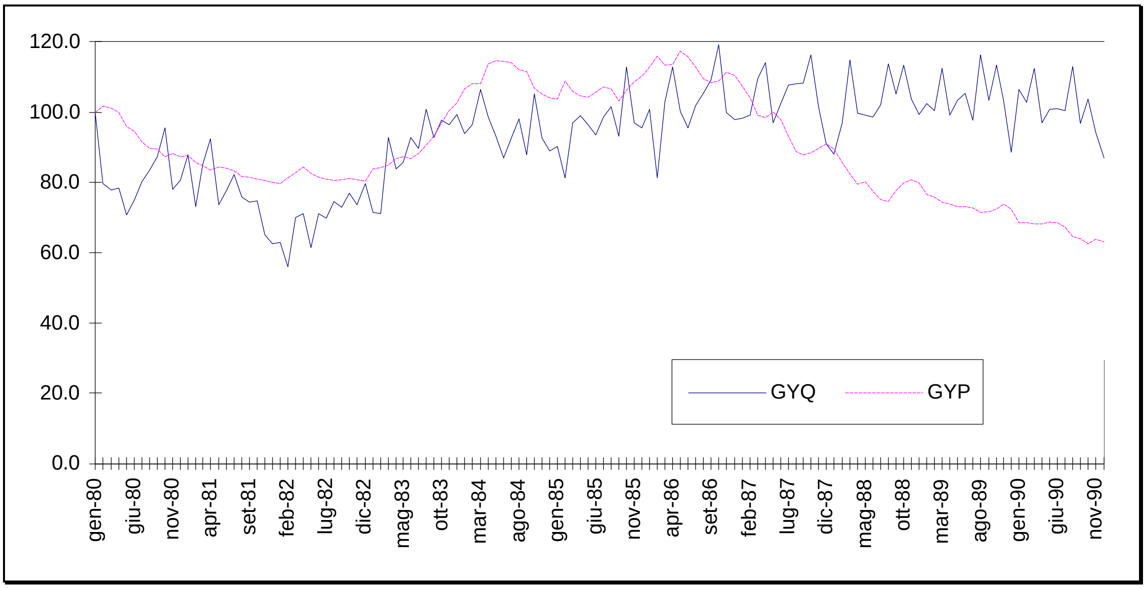

Therefore, graph 2 gives a comparative measure of debt level held by each company, being related to the respective firm's market value. For each producing firm considered in this study, $\frac{DT}{DT + MV}$ is the debt-to-market value ratio, where *DT* stands for "debt-total" and MV for "market value". Graph 2 highlights the sharp change in USG and NGCO financial structures, due to the 1988 and 1986 recapitalizations.

To build up a weighted-average industry capital structure indicator -- which will be used in the econometric model as an independent (explanatory) variable interpreting the average industry debt ratio -- weights to associate with each company are their respective market shares, obtained from annual reports on sales in the 3275 SIC code industry.

The industry price and quantity series in this study are for ½ inch gypsum sheetrock or wallboard. The proxy variables for demand for this industry are industrial production and new residential and commercial construction. The primary input prices for this industry are natural gas, electricity, and the average hourly wage for SIC code 3275. The proxy variable for the substitute product price is wood sheeting price.

To illustrate the industry output trend and the fluctuations in price before and after the recapitalizations, graph 3 plots quantity and price time series (quantity and price series are indices and are normalized so that 1980 = 100). From the chart below we can assert price and quantity produced have had a different trend; gypsum board production has been relatively stable with a slight upward trend, while its price, from the end of 1986 (NGCO recapitalization date) till 1990, is characterized by a strong downward trend.

*Graph 3:* Quantity (GYQ) and price (GYP) in the gypsum wallboard industry.



## 2.3 The high-density polyethylene industry.

Polyethylene products are oil-based plastics used in almost every industry. The most common examples are films, sheeting, cans in the food industry (substituting the aluminum and glass cans) and polyethylene moldings in the automobile industry.

Following the American "standard industrial classification", this product belongs to SIC code 2821[18] which I referred to for identifying the respective producer price index and average hourly wage.

Firms manufacture polyethylene chemicals in a continuous-flow process, using large plants dedicated to producing individual chemicals. These plants cannot generally be reconfigured to produce other chemicals.

The high-density polyethylene industry, like the gypsum board industry, is dominated by a limited number of large firms. Below in the footnote[19], is reported, in

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[18]SIC Code: 2821 Plastics Materials, Synthetic Resins.
(from "*General Business File (Infotrac)*", Fuqua School of Business Library)
*Description:*
Establishments primarily engaged in manufacturing synthetic resins, plastics materials, and nonvulcanizable elastomers. Important products of this industry include: cellulose plastics materials; phenolic and other tar acid resins; urea and melamine resins; vinyl resins; styrene resins; alkyd resins; acrylic resins; **polyethylene resins**; polypropylene resins; rosin modified resins; coumarone-indene and petroleum polymer resins; miscellaneous resins, including polyamide resins, silicones, polyisobutylenes, polyesters, polycarbonate resins, acetal resins, and fluorohydrocarbon resins; and casein plastics. Establishments primarily engaged in manufacturing fabricated plastics products or plastics film, sheet, rod, nontextile monofilaments and regenerated cellulose products, and vulcanized fiber are classified in Industry Group 308, whether from purchased resins or from resins produced in the same plant. Establishments primarily engaged in compounding purchased resins are classified in Industry 3087. Establishments primarily manufacturing adhesives are classified in Industry 2891.
*Includes:* Acetal resins, Acetate, cellulose (plastics), Acrylic resins, Elastomers, nonvulcanizable (plastics), Ethyl cellulose plastics,.... Molding compounds, plastics, Nitrocellulose plastics (pyroxylin), Nylon resins, Petroleum polymer resins, Phenol-furfural resins, Phenolic resins, Phenoxy resins, Phthalic alkyd resins, Phthalic anhydride resins, Polyacrylonitrile resins, Polyamide resins, Polycarbonate resins, Polyesters, **Polyethylene resins**, Polyhexam-ethylenediamine adipamide resins, Polyisobutylenes, Polymerization plastics, except fibers, Polypropylene resins, Polystyrene resins, Polyurethane resins, Resins, synthetic.....

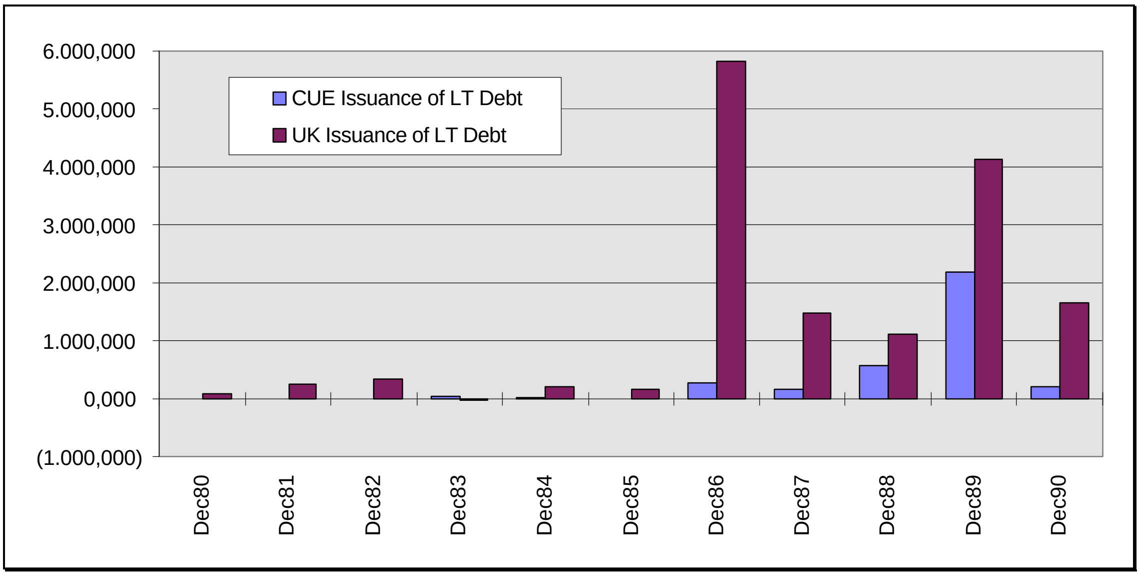
[19] **AlliedSignal Inc.** Revenue: $12,817.0 M Sales, Employees: 87500. **Amoco Chemical Co.** Revenue: $3,773.0 M Sales, Employees: 18000. **Chevron Chemical Corp.** Revenue: $2,872.0 M Sales, Employees: 4200. **Dow Chemical Co.** Revenue: $20,015.0 M Sales, Employees: 53700. **E.I. du Pont de Nemours and Company Inc.** Revenue: $39,333.0 M Sales, Employees: 107000. **Exxon Chemical Co.** Revenue: $8,641.0 M Sales, Employees: 15950. **Occidental Chemical Corp.** Revenue: $4,000.0 M Sales, Employees: 11000. (Occidental Chemical Corp., in 1987, bought all Cain Inc.'s polyethylene plants. Cain Inc. was formed by a leverage buyout of DuPont high-density polyethylene plants in 1987. Because of this complicated identification and its rather small market share relative to the othres, I've not taken into account Occidental Chemical Corp.'s debt ratio in calculating the average industry debt

alphabetical order, a list of companies which have the highest number of plants producing polyethylene[20]; these firms are identified in 2821 SIC code.

Sales value (in dollars) consider all the various lines of business (segment sales) which belong to the same SIC code (2821). Quantum Chemical, the largest manufacturer in this industry, has only polyethylene plants. In 1988 it recapitalized and its debt-to-market value ratio increased by 40 percentage points. Union Carbide, the second largest producer of polyethylene recapitalized in 1986, increasing its debt-to-market value by 18 percentage points.

Graph 1 emphasizes the size of increasing debt level (issuance of debt[21]) in CUE and UK capital structures, following the two recapitalizations occurred respectively in 1988 and 1986. Firms are identified by their official ticker symbol[22].

*Graph 1:* Issuance of debt by CUE and UK (millions of dollars).




Graph 2, giving a comparative measure of debt level held by CUE and UK, being related to their respective market value, highlights the sharp change in CUE and UK

ratio). **Phillips Petroleum Co.** Revenue: $12,367.0 M Sales, Employees: 18400. **Quantum Chemical Corp.** Revenue: $2.367.4 M Sales, Employees: 8730. **Union Carbide Corp.** Revenue: $4,865.0 M Sales, Employees: 12004.

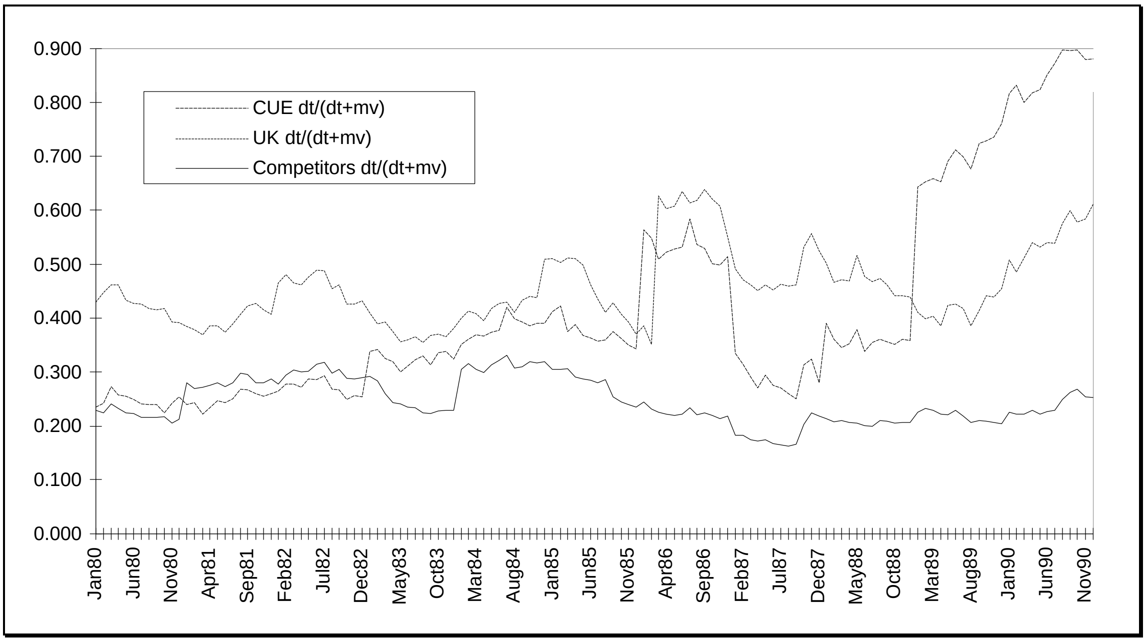
[20]Some of these companies are highly differentiated, therefore, their sales are the total amount of revenues of different line of business.

[21]"*Issuance of long-term debt*" represents the amount of funds generated from issuance of long-term debt. This item includes: increase in long-term and short-term debt when combined; long-term debt issued for or assumed for an acquisition; proceeds from bonds, capitalized lease obligations, or note obligations; reclassification of current debt to long-term debt.

[22]**CUE** = Quantum Chemical Corp.; **UK** = Union Carbide Corp.

financial structures and compares these two firms' debt-to-market value ratios to the average competitors' one.

*Graph 2:* Variations in debt-to-market value ratio, DT/(DT+MV), for the major firms.




The graph above points out the low value of the average (calculated without CUE and UK values) industry debt.

Since the individual firm sales numbers for polyethylene were not available, the individual firm debt-to-market value ratios have been weighted -- to build up a weighted-average industry capital structure indicator[23] -- by the percentage firm capacity of total industry capacity, obtained from the January annual issue of *Modern Plastics*.

In this industry, several major firms have low debt ratios. Large plant sizes provide some barriers to entry. The industry price and quantity series, in the econometric test, are for high-density polyethylene. The demand-shift instruments used for this industry are industrial production and auto production. The input series used for this product are oil, electricity and the hourly wage for 2821 SIC code. The proxy variable for the substitute product price is aluminum cans price.

[23] The weighted-average industry debt ratio is $\sum_i s_i \frac{DT_i}{DT_i + MV_i}$, where *i* is the number of producing firms and $s_i$ the respective market share.

To illustrate the industry output trend and the fluctuations in price before and after the recapitalizations, graph 3 plots quantity and price time series (quantity and price series are indices and are normalized so that 1980 = 100).

*Graph 3:* Quantity (POQ) and price (POP) of high-density polyethylene.


We can observe how prices increased drastically for polyethylene approximately one year prior to the Quantum Chemical's ricapitalization announcement (1988), while quantity sold seems to change its trend from a slight upward trend, throughout the period 1980-1988, to a constant (almost downward) course.

## 3. *Supply and demand in product market.*

### 3.1 Methodology and economic theory.

This section presents the methodology[24] and results for the product market tests of the interaction between output and capital structure. The tests examine quantity and price movements, controlling for changes in input prices and the level of production. The tests separate price changes resulting from changes in marginal cost from those resulting from changes in output. This separation occurs because the tests involve estimating how prices respond to marginal cost, not to sunk fixed costs. The equations estimated include quantity, controlling for returns to scale.

The first step is specifying demand functions for products and marginal cost functions for firms. From these equations an industry supply relationship is derived, aggregating from the firm level. Initially, these function do not incorporate any dependence on capital structure which will be considered as independent variable in the model presented in the following section.

The general form of the *inverse demand function* is:

$$P_t = D(Q_t, Z_t, \mathbf{Y}_t, \alpha, \varepsilon_t) \qquad (1)$$

where $P$ is price, $Q$ is industry quantity, $Z$ is the price of a substitute product and $\mathbf{Y}$ is a vector of exogenous variables shifting demand, observed by all firms in the industry contemporaneously. The $\alpha$ are parameters of the demand equation, while $\varepsilon$ represents unobserved shocks to demand that are econometric error in the estimation.

The general form of the firm's cost function can be written:

$$C_{it} = C(Q_{it}, \mathbf{W}_t, \beta, \mu_{it}) \qquad (2)$$

where $\mathbf{W}$ is a vector of input prices and $\beta$ is a vector of parameters of the cost function. The last term, $\mu$, represents a random cost shock from such items as input price shocks. From equation (2) follows firm-level marginal cost:

$$MC_{it} = \frac{\partial C}{\partial Q_{it}} = c(Q_{it}, \mathbf{W}_t, \beta, \mu_{it}). \qquad (3)$$

[24]This general framework follows Bresnahan (1989) and Phillips (1995).

Individual firms maximize profits by choosing quantity as in a Cournot model. Referring to firm-*i* profits as $\pi_i = p(Q)q_i - c(q_i)$, where $Q = \sum q_i$ and $c(q_i)$ is the cost function, and maximizing $\pi_i$ with respect to output[25], will have:

$$p(Q) = MC_i - p'(Q)q_i . \qquad (4.1)$$

The firm picks the level of output that sets "perceived" marginal revenue, $p'(Q)q_i$, equal to marginal cost $MC_i$. Referring to the equations (1) and (3), we can write the firm-level "supply function" as:

$$P_t = MC_{it} - \theta_{it} D'^q(Q_t, \mathbf{Y}_t, Z_t, \alpha, \varepsilon_t)Q_{it} \qquad (4.2)$$

where $D'^q(\bullet)$ represents the derivative with respect to output of the inverse demand function. The parameter θ indicates the intensity of competition. As a matter of fact, rearranging *MR* function to highlight the demand elasticity and rewriting condition (4.1) in terms of *MR* and *MC* equality, we have $MR_i = p(Q)\left[1 + p'(Q)\cdot\frac{q_i}{Q}\cdot\frac{Q}{p(Q)}\right] = MC_i$ which can also be written as $p(Q)\left[1 + \frac{s_i}{\varepsilon(Q)}\right] = MC_i$ where $s_i = \theta_i = \frac{q_i}{Q}$ represents firm-*i* market share.

When $\theta = 1$ the firms in the industry jointly produce the monopoly level of output and equation (4.2) reduces to the standard monopoly condition, $MR = MC$. When $\theta \in (0,1)$ the firms produce at a level such that price is higher than marginal cost, as in an oligopoly. When $\theta = 0$ the industry is perfectly competitive with price equal to marginal cost.

Since the econometric test is not conducted at the firm level, equation (4.2) must be aggregated at the industry level once we have given specific functional form for demand and marginal cost. The general form of the *industry supply function* to be estimated in our empirical analysis is:

$$P_t = c(Q_t, \mathbf{W}_t, \beta, \mu) - \theta D'^q(Q_t, Z_t, \mathbf{Y}_t, \alpha, \varepsilon_t)Q_t \qquad (4.3)$$

Shocks and shifts to product demand allow identification of the effect of quantity produced on the industry price. The exogenous variables, **Y**, which are general demand variable and substitute product's price, *Z*, rotate and shift the demand curve; without perfect competition, rotations in the demand curve will cause the firms output decisions to change as the elasticity of demand changes. Any changes in the perceived optimal

[25]Under the hypothesis of product homogeneity within the industry.

response of competitors because of capital structure changes will also cause a firm's output decisions to change.

## 3.2 Estimating how financial structure interacts with product market.

The firms' financial structure has been incorporated in the demand and supply equations by allowing parameters to depend on the average debt ratio of the industry. The industry supply and demand equations are estimated in a simultaneous equation framework, using two-stage instrumental variable technique (IV).

To test the interaction of price and quantity with capital structure, the industry supply relationship is derived by assuming a specific form for the industry demand function and the firm production function.

- *HYPOTHESIS 1:* the *total industry demand* is assumed to be a loglinear function of price as follows:

$$q_t = \alpha_0 + \alpha_1 p_t + \boldsymbol{\alpha}_2' \mathbf{y}_t + \alpha_3 r_t + \varepsilon_t \qquad (1.1)$$

where lower case variables indicate log transformations of those ones inside the (1) of the previous section. Since $r_t = \ln(P_t / Z_t)$, where *Z* is the price of a substitute product, we can rewrite the (1.1) as follows:

$$q_t = \alpha_0 + (\alpha_1 + \alpha_3) p_t + \boldsymbol{\alpha}_2' \mathbf{y}_t + \alpha_3 z_t + \varepsilon_t \qquad (1.2)$$

where *q* is quantity, *p* is price, ***y*** is a vector of demand shift variables, such as industrial production, and ε represents econometric error. Rearranging (1.2) we have the *inverse demand function:*

$$p_t = (q_t - \alpha_0 - \boldsymbol{\alpha}_2' \mathbf{y}_t + \alpha_3 z_t + \varepsilon_t) / (\alpha_1 + \alpha_3) \qquad (1.3)$$

To build up the industry supply function we have to define a specific form for the individual firms' production functions by which we'll specify the marginal cost function.

- *HYPOTHESIS 2:* we assume that the firms produce using *N* inputs, according to a Cobb-Douglas production function:

$Q_{it} = A_i * X_1^{a_{1i}} X_2^{a_{2i}} \ldots\ldots X_N^{a_{Ni}}$; the term $X_j^{a_{ji}}$ (*j* = 1, 2,....N) denotes the quantity of input *j* used in production for firm *i*. $A_i$ represents a firm *i* specific technology shift parameter, and $a_i = \sum_{j=1}^{N} a_{ji}$ indexes returns to scale. Under constant returns to scale $a_i = 1$; under increasing (decreasing) returns to scale $a_i$ is greater (lower) than 1.

Taking input prices as given and minimizing cost for any level of output, the marginal cost function -- whose more general form is $MC_{it} = c(Q_{it}, \mathbf{W}_t, \boldsymbol{\beta}, \mu_{it})$ --, after log transformations, is:

$$mc_{it} = \left(\frac{1-a_i}{a_i}\right) q_{it} + \sum_{j=1}^{N} \left(\frac{a_{ji}}{a_i}\right) w_{jit} - \frac{1}{a}\log(A_{it}) + \mu_{it} \qquad (2.1)$$

where *mc* is log marginal cost (*MC*) and small letters indicate logs of the variables included in (3) of previous section. In the equation (2.1) the term $(1-a_i)/a_i$ indexes returns to scale for the firm. This specification thus directly controls for changes in returns to scale and changes in input prices. Finally, $A_i$ represents a technological shift parameter which we assume to be constant across time and firms, given the mature industries examined. For simplicity we can write:

$$\beta_0 = -\frac{1}{a} * \log(A), \qquad \beta_{1i} = \frac{1-a_i}{a_i}, \qquad \beta_{ji} = \frac{a_{ji}}{a_i},$$

where $\beta_{ji}$ is the generic term in the $(N \times 1)$ vector of parameters $\boldsymbol{\beta}_2$. Taking into account these last notations, we can rewrite the (2.1) as follows:

$$mc_{it} = \beta_0 + \beta_{1i} q_{it} + \boldsymbol{\beta}'_{2i} \mathbf{w}_{it} + \mu_{it} \qquad (2.2)$$

where $\mathbf{w}_{it}$ is the input prices vector in period *t*.

To introduce the financial structure variable in the econometric model we recall here below the general form for the firm-level supply function[26] - equation (4.2) in section 3.1:

$$P_t = MC_{it} - \theta_{it} * D'^{q}(Q_t, Z_t, \mathbf{Y}_t, \boldsymbol{\alpha}, \varepsilon_t) Q_{it}. \qquad (3)$$

In an oligopoly, with Cournot competition, $\theta_{it} = s_{it} = \frac{q_{it}}{q_t}$ represents the market share of firm *i* in period *t*. Allowing θ to depend on and interact with the firm's debt ratio incorporates capital structure in the simultaneous two-equations framework to estimate[27]. In the econometric model, the average industry debt ratio is included as an independent variable in the industry supply equation. In the estimation, such a ratio varies by time and is a weighted function of individual firms' debt ratio,

[26]Assuming that the products produced by firms are of homogeneous quality, all firms charge equal prices in equilibrium.

[27]In empirical work by Porter (1983), θ is a function of unobservable demand shocks to the industry. As demand shocks occur, industry collusion breaks down as cartel members suspect that a rival has cheated, deviating from the collusive outcome.

$DR_i = \dfrac{DT_i}{DT_i + MV_i}$ (where *DT* stands for "*debt-total*" and *MV* for "*market value*"),

weighted by their market share. Therefore, the independent variable to be incorporated in the model is:

$$(Debt\ ratio)_t = DR_t = \sum_i s_i * DR_{it}$$

where $s_i$ is firm *i*'s market share.

The model thus captures whether price movements also depend on the capital structures of firms. If low amounts of free cash flow act as a credible bond that decreases investment and industry output, the coefficient on the debt ratio will be positive (Glazer, Poitevin). A negative coefficient will result when a firm increases output subsequent to the ricapitalization (Brander and Lewis, Maksimovic).

Calculating the derivative of the inverse demand function (1.3) and substituting it and the marginal cost function (2.2) in the equation (3), solving for *p* (taking into account log transformations) we obtain firm-level supply equation depending (also) on the industry financial structure:

$$p_t = \beta_0 + \beta_{1i} q_{it} + \boldsymbol{\beta}'_{2i} \mathbf{w}_{it} + \gamma_i * (Debt\ ratio)_{it} + \nu_{it} \qquad (4.1)$$

Adding up these firm-level supply equations, weighted by firm market shares, gives an *industry supply* relationship that can be estimated with industry price and quantity data:

$$p_t = \beta_0 + \beta_1 q_t + \boldsymbol{\beta}'_2 \mathbf{w}_t + \gamma * (Debt\ ratio)_t + \nu_t \qquad (4.2)$$

Whether θ, and thus γ, is affected by the debt ratio tests whether capital structure influences the industry supply relationship. If no structural change occurs, or the firms have no market power, the term  (and thus θ) will be zero. Calculating the partial derivative with respect to the debt ratio, $\dfrac{\partial p_t}{\partial (Debt\ ratio)_t} = \gamma$, we can see that output price, controlling for demand and input prices, increases when γ is positive and decreases when γ is negative.

Therefore, the simultaneous two-equations framework which determines the equilibrium industry price and quantity can be written as follows:

- $q_t = \alpha_0 + (\alpha_1 + \alpha_3) p_t + \boldsymbol{\alpha}'_2 \mathbf{y}_t + \alpha_3 z_t + \varepsilon_t$ (demand)
- $p_t = \beta_0 + \beta_1 q_t + \boldsymbol{\beta}'_2 \mathbf{w}_t + \gamma * (Debt\ ratio)_t + \nu_t$ (supply)

where **α**, **β** and γ are the parameters to be estimated.

Under any theory of oligopoly, changes in the elasticity of demand shift the perceived marginal revenue of firms. If capital structure changes affect their perceived marginal revenue, firms will make different output decisions. Firms' responses to changes in relative prices and demand shocks will vary depending upon capital structure. For this reason, increased debt can cause firms to credibly commit to changing output decisions. Industry output is affected by capital structure as firm and its rivals adjust their output.

## 4. *Specifying the econometric model and estimating method.*

Making the technology constraints explicit inside the marginal cost function, which is a part of our industry supply relationship, the simultaneous two-equations model to be estimate can be written as follows:

- $q_t = \alpha_0 + (\alpha_1 + \alpha_3) p_t + \boldsymbol{\alpha}_2' \mathbf{y}_t + \alpha_3 z_t + \varepsilon_t$ (1) demand
- $p_t = \beta_0 + \left( \frac{1}{\sum_{j=1}^{N} \beta_{2j}} - 1 \right) q_t + \sum_{j}^{N} \beta_{2j} w_{jt} + \beta_3 * (Debt\ ratio)_t + \nu_t$ (2) supply

where $\sum \beta_{2j}$ indexes returns to scale in the producing process.

The first step in specifying the structure of the econometric model has been analyzing the *stationarity* of the variables included in equations (1) and (2). In fact, we know that a non-stationary stochastic process, or integrated of order *d*, $I(d)$, must be differenced *d* times in order to make it stationary, or integrated of order zero, $I(0)$.

To test for stationarity of data, each variable was tested by the Augmented Dickey-Fuller test (or ADF), also called unit roots test[28].

As resulted of ADF test, quantity and price series for each industry are not stationary. Since almost all the variables in the model did not pass the ADF test, I estimated the parameters in equations (1) and (2) differencing (through the *first-difference operator* $\Delta$, we have $\Delta y_t \equiv y_t - y_{t-1}$) the series in order to make sure of their trend-stationarity. Dealing with $I(0)$ variables we avoid the explosive trend of mean, variance and covariance, characterizing non-stationary stochastic processes, affects the values of the estimates and the regression indicators.

The classical approach to dealing with integrated variables has been to difference them as many times as needed to make them stationary (transforming variables from *levels* to *differences* through the difference-operator $\Delta$). This approach has the merit of simplicity. Once all series have been transformed to stationarity, dynamic regression models may be specified in the usual way and standard asymptotic theory apply. The problem with this approach is that differencing eliminates the opportunity to estimate any relationships between the *levels* of the dependent and independent variables. As a matter of fact, the concept of *cointegration*[29] itself suggests that such relationships can exist and

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[28] The extended output of ADF test for the endogenous variables (quantity and price) in the two industries and all the other variables included in the model is available to the author.

[29] We know that variables which are $I(1)$ tend to diverge as $n \to \infty$ because their unconditional variances are proportional to *n*. Thus it might seem that such variables could never be expected to obey any sort of

are often of considerable economic interest; therefore, it's reasonable to specify a model capable to catch these important long-run relationships through the estimating process.

A structure allowing this sophisticated analysis is the ECM (*Error Correction Model*) form, which can be written as:

$$\Delta y_t = \mathbf{z}_t \boldsymbol{\alpha} + (\beta_1 - 1)(y_{t-1} - \lambda x_{t-1}) + \gamma_0 \Delta x_t + u_t, \qquad (3)$$

with $u_t \sim$ IID (0, $\sigma^2$). The dependent variable is $y_t$ and the independent one is $x_t$, which can be, in general, a vector of independent variables $\mathbf{x}_t$. We assume that these two variables are $I(1)$ and cointegrated; this implies that the error correction term, $(\beta_1 - 1)(y_{t-1} - \lambda x_{t-1})$, is $I(0)$. The row vector $\mathbf{z}_t$ includes a constant and any other independent variable which is not stochastic or stationary, $I(0)$.

The difference between $y_{t-1}$ and $\lambda x_{t-1}$ measures the extent to which the long-run equilibrium relationship between $x_t$ and $y_t$ is not satisfied. Consequently, the parameter $(\beta_1 - 1)$ can be interpreted as the proportion of the resulting (long-run) disequilibrium that is reflected in the movement of $y_t$ in one period ($\Delta y_t$). In other words, the term $(y_{t-1} - \lambda x_{t-1})$ is a measure of the distance from the desired equilibrium level of the system; $(\beta_1 - 1)$ is a correction factor to the $\Delta y_t$ and $\Delta x_t$ movements.

It's clear how the ECM can constitute a good choice, in specifying the econometric model's structure, even when the equation to be estimated doesn't include any non-stationary variable. Splitting the long-run form the short-run dynamic allows to give an economic explanation of the differences (in sign) between the single-period variations and the long-run trend of the variables.

Having chosen a suitable structure to estimate equations (1) and (2), we have to show how constraints between the coefficients of equations (1) and (2) remain active despite the reparametrization occurred by moving from the loglinear to the ECM structure. This means to express the parameters of equation (3) in terms of those we have in the loglinear form.

We know that ECM is the non-linear reparametrization of the linear model ADL (*Autoregressive Distributed Lag)*. Therefore, the ECM model can always be reconverted into the "original" ADL form:

ADL (1, 1) $\qquad y_t = \beta_1 y_{t-1} + \gamma_0 x_t + \gamma_1 x_{t-1} + u_t \qquad (4)$

ECM $\qquad \Delta y_t = (\beta_1 - 1)(y_{t-1} - \lambda x_{t-1}) + \gamma_0 \Delta x_t + u_t \qquad (5)$

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long-run equilibrium relationship. But in fact it is possible for two or more variables to be *I*(1) and yet for certain linear combinations of those variables to be *I*(0). If that is the case, the variables are said to be *cointegrated.*

where $\lambda \equiv \frac{\gamma_0 + \gamma_1}{1 - \beta_1}$.

Considering a simple case ADL (1, 1) and expressing the parameters of equation (5) in terms of those in (4), it's more immediate to see how constraints on coefficients of the linear form act on those of the ECM. To see how we can respect such constraints in reparametrizing from a generic ADL (p, q) into an ECM form, we need to make some generalizations:

*GENERALIZATION 1.*

An ADL model of order (p, q) can be written in a concise way as follows:

$$\mathrm{B}(L) y_t = \Gamma(L) x_t + \varepsilon_t \tag{6}$$

where $\mathrm{B}(L)$ and $\Gamma(L)$ are two polynomials, respectively of degree p and q, in the lag operator $L$:

$$\mathrm{B}(L) = \left(1 - \beta_1 L - \beta_2 L^2 - \ldots\ldots - \beta_p L^p\right) \tag{6.1}$$

$$\Gamma(L) = \left(\gamma_0 - \gamma_1 L - \gamma_2 L^2 - \ldots\ldots - \gamma_q L^q\right) \tag{6.2}$$

Breaking up the polynomials $\mathrm{B}(L)$ and $\Gamma(L)$ as follows:

(a) $\mathrm{B}(L) = \mathrm{B}(1) L + \mathrm{B}^*(L)\Delta$

(b) $\Gamma(L) = \Gamma(1) L + \Gamma^*(L)\Delta$

where $\mathrm{B}(1)$ and $\Gamma(1)$ indicate the respective polynomials' values by substituting $L$ with 1; $\Delta$ is the first-difference operator. The polynomials $\mathrm{B}^*(L)$ and $\Gamma^*(L)$ are defined as:

$$\mathrm{B}^*(L) = \beta_0^* - \beta_1^* L - \ldots\ldots - \beta_p^* L^{p-1}$$

$$\Gamma^*(L) = \gamma_0^* - \gamma_1^* L - \ldots\ldots - \gamma_q^* L^{q-1}$$

where the coefficients are respectively:

$$\beta_0^* = 1, \quad \beta_1^* = -\sum_{j=1}^{p-1} \beta_{j+1}, \quad ::::: \quad \beta_k^* = -\sum_{j=1}^{\text{p-k}} \beta_{j+k}, \quad ::::: \quad \beta_{p-1}^* = -\beta_p.$$

for the polynomial $\mathrm{B}^*(L)$ and

$$\gamma_0^* = \gamma_0, \quad \gamma_1^* = -\sum_{j=1}^{q-1} \gamma_{j+1}, \quad ::::: \quad \gamma_k^* = -\sum_{j=1}^{\text{q-k}} \gamma_{j+k}, \quad ::::: \quad \gamma_{q-1}^* = -\gamma_q.$$

for $\Gamma^*(L)$. Substituting (a) and (b) in equation (6) we can write equations (4) and (5) in a more general form:

ADL (p, q) $$\mathrm{B}(1) L y_t + \mathrm{B}^*(L)\Delta y_t = \Gamma(1) L x_t + \Gamma^*(L)\Delta x_t + u_t \tag{7}$$

ECM $$\mathrm{B}^*(L)\Delta y_t = -\mathrm{B}(1) \cdot \left[ y_{t-1} - \frac{\Gamma(1)}{\mathrm{B}(1)} x_{t-1} \right] + \Gamma^*(L)\Delta x_t + u_t \tag{8}$$

where $\frac{\Gamma(1)}{\mathrm{B}(1)} \equiv \lambda \equiv \frac{\gamma_0 + \gamma_1 + \gamma_2 + ...... + \gamma_q}{1 - \beta_1 + \beta_2 + ...... + \beta_p}$ represents the long-run coefficient.

Knowing the general "rule" which allows us to write an ECM by using the corresponding ADL model's coefficients, it will be simple passing from one form to the other, given the specific degree of polynomials $\mathrm{B}(L)$ and $\Gamma(L)$, without loosing the relationship between the coefficients of the reparametrized model and those of the "original" model. This is very important especially when all we know (as in equations (1) and (2)) is the form of constraints between coefficients only for the loglinear structure. The steps illustrated above ensure that such constraints exist even after the ECM reparametrization.

*GENERALIZATION 2.*

These general remarks aim at defining the relationship between an ADL model and its ECM reparametrization in the case in which we have more than one explanatory variable. In general, using the (6), we can define an ADL (p, q) in k *explanatory variables* as follows:

$$\mathrm{B}(L) y_t = \Gamma_1(L) x_{1t} + ...... + \Gamma_k(L) x_{kt} + \varepsilon_t \qquad (9)$$

Using the polynomials (a) and (b), we can rewrite the relationship between equations (7) and (8) as follows:

ADL (p,q)

$$\begin{aligned} \mathrm{B}(1) L y_t + \mathrm{B}^*(L) \Delta y_t &= \Gamma_1(1) L x_{1t} + ...... + \Gamma_k(1) L x_{kt} \\ &\quad + \Gamma_1^*(L) \Delta x_{1t} + ...... + \Gamma_k^*(L) \Delta x_{kt} + u_t \end{aligned} \qquad (10)$$

ECM

$$\begin{aligned} \mathrm{B}^*(L) \Delta y_t &= -\mathrm{B}(1) \cdot \left[ y_{t-1} - \frac{\Gamma_1(1)}{\mathrm{B}(1)} x_{1t-1} - ...... - \frac{\Gamma_k(1)}{\mathrm{B}(1)} x_{kt-1} \right] \\ &\quad + \Gamma_1^*(L) \Delta x_{1t} + ....... + \Gamma_k^*(L) \Delta x_{kt} + u_t \end{aligned} \qquad (11)$$

where the error correction term represents (inside square brackets) a linear combination of k explanatory variables, which are, by assumption, cointegrated. Thus, in this case we'll have a ($k \times 1$) vector of cointegration coefficients (or "long-run" coefficients):

$$\lambda^{\mathrm{T}} \equiv [\lambda_1 \quad \lambda_2 \quad : \quad : \quad \lambda_k] \equiv \left[ \frac{\Gamma_1(1)}{\mathrm{B}_1(1)} \quad \frac{\Gamma_2(1)}{\mathrm{B}_2(1)} \quad : \quad : \quad \frac{\Gamma_k(1)}{\mathrm{B}_k(1)} \right].$$

Taking into account all these remarks with refer to the specific case of our demand and supply equations for two selected industries, (1) and (2), we can define in a more precise way the structure for the two equations to be estimated.

Differently from Phillips (1995)[30], in the empirical analysis, I adopt the ECM form referable to an ADL (1, 1) and, when the dynamic of the model is not sufficient to explain the economic relationship between the ECM form variables, to an ADL (1, 2). Since we have *k* explanatory variables we can write the ECM model as follows:

ECM $$\Delta y_t = \mathbf{z}_t \boldsymbol{\alpha} + (\beta_1 - 1)\left(y_{t-1} - \boldsymbol{\lambda}^{\mathrm{T}} \mathbf{x}_{t-1}\right) + \boldsymbol{\gamma}_0^{\mathrm{T}} \Delta \mathbf{x}_t + u_t \qquad (12)$$

where the row vector $\mathbf{z}_t$ includes a constant and any other independent variable which is not stochastic or stationary, $I(0)$, while the other vectorial notations indicate:

$$\boldsymbol{\lambda}^{\mathrm{T}} \equiv \begin{bmatrix} \lambda_1 & \lambda_2 & : & : & \lambda_k \end{bmatrix} \equiv \begin{bmatrix} \dfrac{\gamma_{0,1} + \gamma_{1,1}}{1-\beta_1} & \dfrac{\gamma_{0,2} + \gamma_{1,2}}{1-\beta_1} & : & : & \dfrac{\gamma_{0,k} + \gamma_{1,k}}{1-\beta_1} \end{bmatrix} \qquad (12.1)$$

$$\boldsymbol{\gamma}_0^{\mathrm{T}} \equiv \begin{bmatrix} \gamma_{0,1} & \gamma_{0,2} & : & : & \gamma_{0,k} \end{bmatrix} \qquad (12.2)$$

$$\mathbf{x}_t = \begin{bmatrix} x_1 & x_2 & : & : & x_k \end{bmatrix} \qquad (12.3)$$

with $\mathbf{x}_t$ a ($k \times 1$) column vector.

If $\lambda$ were known, there would clearly be no problem estimating (12) by least squares. The regressand and all the regressors would be either non-stochastic or $I(0)$; the estimates of $\boldsymbol{\alpha}$, $\beta$ and $\boldsymbol{\gamma}$ would be consistent and asymptotically normal. But in most cases $\lambda$ will not be known.

One of the simplest ways to proceed is the *Engle-Granger two-step method* proposed by Engle and Granger (1987). The first step is to regress $y_t$ on $\mathbf{x}_t$, including a constant term and possibly a trend if the latter appears in $\mathbf{z}_t$. This will yield a super-consistent estimate[31] of $\lambda$, say $\tilde{\lambda}$. The second step is to replace $\lambda$ by $\tilde{\lambda}$ in (12) and then estimate that equation using OLS. Because of the super-consistency of $\tilde{\lambda}$, Engle and Granger are able to show that the resulting estimates of the other parameters (in equation 12) are asymptotically the same as they would be if $\lambda$ were known.

Although the principal merit of the Engle-Granger two-step procedure is simplicity, there is a good deal of Monte Carlo evidence that it often does not work very well in finite samples[32]. The problem is that $\tilde{\lambda}$ often seems to be severely biased. This bias then causes the other parameter estimates (second step) to be biased as well. The problem appears to be less severe when the $R^2$ of the cointegrating regression is close to 1. Davidson and Mackinnon (1993) suggest a simple alternative to the Engle-Granger two-step procedure. Starting from the ECM form of equation (12),

[30]Whose test considers a loglinear model without transforming variables from levels to differences.

[31]When $y_t$ through $\mathbf{x}_t$ are cointegrated, the OLS estimates from regressing $y$ on $\boldsymbol{x}$ will be *super-consistent:* instead of approaching their true values at a rate proportional to $n^{-1/2}$, the OLS estimates will approach them at a rate proportional to $n^{-1}$.

ECM $\Delta y_t = \mathbf{z}_t \boldsymbol{\alpha} + (\beta_1 - 1)\left(y_{t-1} - \boldsymbol{\lambda}^{\mathrm{T}} \mathbf{x}_{t-1}\right) + \boldsymbol{\gamma}_0^{\mathrm{T}} \Delta \mathbf{x}_t + u_t$ (12)

we can define $\beta^* = (\beta_1 - 1)$ and rearranging the (12) as follows:

$$\Delta y_t = \mathbf{z}_t \boldsymbol{\alpha} + \beta^* y_{t-1} + \beta^* \boldsymbol{\lambda}^{\mathrm{T}} \mathbf{x}_{t-1} + \boldsymbol{\gamma}_0^{\mathrm{T}} \Delta \mathbf{x}_t + u_t \quad (13)$$

Indicating with $\boldsymbol{\delta}$ the vector of coefficients of $\mathbf{x}_{t-1}$ (obtained by the scalar product of $\beta^*$ by $-\boldsymbol{\lambda}$), implicitly we'll have that $\boldsymbol{\delta} = -\beta^* \boldsymbol{\lambda}$; thus equation (12) can be reparametrized as follows:

ECM(r) $\Delta y_t = \mathbf{z}_t \boldsymbol{\alpha} + \beta^* y_{t-1} + \boldsymbol{\delta}^{\mathrm{T}} \mathbf{x}_{t-1} + \boldsymbol{\gamma}_0^{\mathrm{T}} \Delta \mathbf{x}_t + u_t$ (14)

With this structure the practical problems of biased estimates, mentioned above, turn out to be much less severe than one might expect. The key results for regressions like equation (14) proved by Sims, Stock and Watson (1990), are briefly treated in Davidson and Mackinnon (1993)[33].

Applying the (14) to the demand and supply equations for each industry and taking into account the relationships between the coefficients of loglinear form (1) and (2), in passing into the ECM structure (as illustrated by the "generalizations" above), I estimated the simultaneous two-equation system using instrumental variable technique (IV). Knowing that $\boldsymbol{\delta} = -\beta^* \boldsymbol{\lambda}$, from the estimate of $\tilde{\boldsymbol{\delta}}$ and $\tilde{\beta}^*$ we will easily derive the estimate of the long-run coefficients vector $\tilde{\boldsymbol{\lambda}} = -\dfrac{\tilde{\boldsymbol{\delta}}}{\tilde{\beta}^*}$.

The econometric test applied to the two selected industries consists in estimating industry demand and supply equations in the reparametrized ECM form we have discuss above:

ECM(r)[34] $\Delta y_t = \mathbf{z}_t \boldsymbol{\alpha} + \beta^* y_{t-1} + \boldsymbol{\delta} \mathbf{x}_{t-1} + \boldsymbol{\gamma}_0 \Delta \mathbf{x}_t + \boldsymbol{\gamma}_1 \Delta \mathbf{x}_{t-1} + u_t$ (15)

Writing parameters in (15) in terms of its loglinear form coefficients:

ADL (1,2) $y_t = \beta_1 y_{t-1} + \boldsymbol{\gamma}_0 \mathbf{x}_t + \boldsymbol{\gamma}_1 \mathbf{x}_{t-1} + \boldsymbol{\gamma}_2 \mathbf{x}_{t-2} + u_t$ (16)

to which the ECM form can always be led back, we'll have:

$\beta^* = (\beta_1 - 1)$ scalar,

$\boldsymbol{\delta} = [\delta_1 \quad \delta_2 \quad : \quad : \quad \delta_k] = [\gamma_{0,1} + \gamma_{1,1} \quad \gamma_{0,2} + \gamma_{1,2} \quad : \quad : \quad \gamma_{0,k} + \gamma_{1,k}]$ $(1 \times k)$, (a)

$\boldsymbol{\gamma}_0 = [\gamma_{0,1} \quad \gamma_{0,2} \quad : \quad : \quad \gamma_{0,k}]$ $(1 \times k)$ row vector, (b)

$\boldsymbol{\gamma}_1 = [-\gamma_{2,1} \quad -\gamma_{2,2} \quad : \quad : \quad -\gamma_{2,k}]$ $(1 \times k)$ row vector. (c)

Notation like $\gamma_{1,k}$ indexes the coefficient associated to the *k-variable, 1-period* lagged.

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[32]Banerjee, Dolado, Hendry and Smith (1986); Banerjee, Dolado, Galbraith and Hendry (1993).
[33]Chapter 20 in "*Estimation and Inference in Econometrics*." Oxford University Press.
[34]In this case referable to an ADL (1, 2)

To keep constraints active, between coefficients of the loglinear form, we'll have to estimate (15) substituting its parameters by the corresponding expressions (a), (b) and (c), functions of equation (16) coefficients. Such a constraints are explicit in the general *loglinear* forms of industry demand and supply equations, we'll refer to in the econometric test:

- $q_t = \alpha_0 + (\alpha_1 + \alpha_3) p_t + \boldsymbol{\alpha}_2' \mathbf{y}_t + \alpha_3 z_t + \varepsilon_t$ (17)
- $p_t = \beta_0 + \left( \frac{1}{\sum_{j=1}^{N} \beta_{2j}} - 1 \right) q_t + \sum_{j}^{N} \beta_{2j} w_{jt} + \beta_3 * (DR)_t + \beta_4 (RESD)_t + \nu_t$ (18)

where $\alpha$ indexes a generic parameter in the demand function and $\beta$ the generic parameter in the industry supply function.

In the supply relationship (18), the coefficient on instrumented quantity $q_t$, depending on the sum of input prices ($w_{jt}$) coefficients, controls for returns to scale.

The residuals from the demand equation (*RESD*) are also included as an independent variable in (18) to control for demand shocks effects on output price variations. Green and Porter (1984) predict that a negative demand shock will decrease price as firms can not distinguish between negative demand shocks and "cheating by firms". They predict a positive coefficient.

The *DR* variable represents the average industry debt ratio and its coefficient indexes how financial structure - controlling for effects due to input price variations, returns to scale and demand shocks - affects industry quantity and price decisions. I furthermore included monthly *dummy* variables to control for seasonality of the data.

Because of simultaneity of supply and demand, equations in the econometric test are estimated using instrumental variable method (IV), with instruments for price, in the demand equation (17), and for quantity, in the supply equation, the exogenous variables inside the system.

## *5. Econometric test results of product market and capital structure interaction.*

### 5.1 The gypsum board industry.

Including in the general loglinear equations (17) and (18), discussed in the previous section, the identified variables determining quantity and price in the US gypsum board industry, yields the following simultaneous equations system:

- (1) DEMAND:

$$GYQ_t = COST + \left(\alpha_{0,GYP} + \alpha_{0,PLW}\right)GYP_t + \left(\alpha_{0,CT}\right)CT_t + \left(\alpha_{0,IP}\right)IP_t + \left(\alpha_{0,PLW}\right)PLW_t + \varepsilon_t$$

- (2) SUPPLY:

$$GYP_t = COST + \left(\frac{1}{\beta_{0,NG} + \beta_{0,EL} + \beta_{0,WGY}} - 1\right)GYQ_t + \left(\beta_{0,NG}\right)NG_t + \left(\beta_{0,EL}\right)EL_t + \left(\beta_{0,WGY}\right)WGY_t$$
$$+\left(\beta_{0,DR}\right)DR_t + \left(\beta_{0,RESD}\right)RESD_t + \nu_t$$

where the zero in $\alpha_{0,*}$ and $\beta_{0,*}$ indexes the lag value applied to the series which the parameters refer to ( $x_{t-0} = x_t$ ). The notation used for the variables in the model is:

(DEPENDENT VARIABLES -- ENDOGENOUS):

*GYQ* = Gypsum Quantity; *GYP* = Gypsum Price.

(PROXY VARIABLES FOR DEMAND):

*CT* = Construction-Total (residential and commercial); *IP* = Industrial Production.

(SUBSTITUTE PRODUCT PRICE):

*PLW* = Plywood sheeting.

(INPUTS PRICE IN PRODUCING PROCESS):

*NG* = Natural Gas; *EL* = Electricity; *WGY* = Wage for Gypsum (for SIC 3275).

(OTHER VARIABLES OF INTEREST):

*DR* = Debt Ratio; *RESD* = Residuals from Demand (proxy for demand shocks).

For the reasons we discussed above, we've estimated the demand and supply relationships adopting the following "reparametrized" ECM structure:

$$\Delta y_t = \mathbf{z}_t \boldsymbol{\alpha} + \beta^* y_{t-1} + \boldsymbol{\delta}\mathbf{x}_{t-1} + \gamma_0 \Delta\mathbf{x}_t + \gamma_1 \Delta\mathbf{x}_{t-1} + u_t . \qquad (3)$$

Thus, mantaining the same notation we define in (1), demand equation in gypsum industry will be:

- (4) DOMANDA:

$$\Delta GYQ_t = COST + \sum_{i=1}^{11}\left(\alpha_{D_i}\right)D_i + \left(\alpha_{0,PLW}\right)PLW_t + \left(\alpha_{1,PLW}\right)PLW_{t-1} + \left(\alpha_{2,PLW}\right)PLW_{t-2}$$
$$+\left(\beta^*\right)GYQ_{t-1} + \left(\delta_{GYP}\right)GYP_{t-1} + \left(\delta_{CT}\right)CT_{t-1} + \left(\delta_{IP}\right)IP_{t-1}$$
$$+\left(\gamma_{0,GYP}\right)\Delta GYP_t + \left(\gamma_{0,CT}\right)\Delta CT_t + \left(\gamma_{0,IP}\right)\Delta IP_t$$
$$+\left(\gamma_{1,GYP}\right)\Delta GYP_{t-1} + \left(\gamma_{1,CT}\right)\Delta CT_{t-1} + \left(\gamma_{1,IP}\right)\Delta IP_{t-1} + u_t$$

The $D_i$ variables are 11 "dummy" variables which account for seasonality in demand; *PLW* is a stationary variable, $I(0)$.

Writing parameters of equation (4) in terms of the corresponding ADL form coefficients, will have the following equalities ($\alpha$ refer to the parameters in (1)):

$\beta^* = \left(\beta_{1,GYQ} - 1\right)$,

$\delta_{GYP} = \left[\left(\alpha_{0,GYP} + \alpha_{1,GYP}\right) + \left(\alpha_{0,PLW} + \alpha_{1,PLW}\right) + \left(\alpha_{2,PLW} + \alpha_{2,PLW}\right)\right]$,

$\delta_* = \left(\alpha_{0,*} + \alpha_{1,*} + \alpha_{2,*}\right)$,

$\gamma_{0,*} = \left(\alpha_{0,*}\right)$,

$\gamma_{1,*} = \left(-\alpha_{2,*}\right)$.

Star symbol indexes a generic variable. In a similar way, adopting the ECM structure (3) even for equation (2), will have:

- (5) OFFERTA:

$$\Delta GYP_t = COST + \sum_{i=1}^{11}\left(\beta_{D_i}\right)D_i +$$
$$+\left(\beta^*\right)GYP_{t-1} + \left(\delta_{GYQ}\right)GYQ_{t-1} + \left(\delta_{NG}\right)NG_{t-1} + \left(\delta_{EL}\right)EL_{t-1} + \left(\delta_{WGY}\right)WGY_{t-1}$$
$$+\left(\delta_{DTGY}\right)DR_{t-1} + \left(\delta_{RESD}\right)RESD_{t-1}$$
$$+\left(\gamma_{0,GYQ}\right)\Delta GYQ_t + \left(\gamma_{0,NG}\right)\Delta NG_t + \left(\gamma_{0,EL}\right)\Delta EL_t + \left(\gamma_{0,WGY}\right)\Delta WGY_t$$
$$+\left(\gamma_{0,DTGY}\right)\Delta DR_t + \left(\gamma_{0,RESD}\right)\Delta RESD_t + u_t$$

where, as in (4), the $D_i$ variable are 11 "dummy" variable. For the industry supply relationship, the ECM structure is referable to an ADL (1, 1). As for equation (4), we have estimated (5) substituting ECM form coefficient by the following expressions ($\beta$ refer to the parameters in (2)):

$\beta^* = \left(\beta_{1,GYP} - 1\right)$,

$$\delta_{GYQ} = \left[\left(\frac{1}{\beta_{0,NG} + \beta_{0,EL} + \beta_{0,WGY}} - 1\right) + \left(\frac{1}{\beta_{1,NG} + \beta_{1,EL} + \beta_{1,WGY}} - 1\right)\right],$$

$$\delta_{*} = \left(\beta_{0,*} + \beta_{1,*}\right),$$

$$\gamma_{0,GYQ} = \left(\frac{1}{\beta_{0,NG} + \beta_{0,EL} + \beta_{0,WGY}} - 1\right)$$

$$\gamma_{0,*} = \left(\beta_{0,*}\right),$$

We estimated the simultaneous two-equations system, here above specified, using TSP 4.1 (*Time Series Processor*) software. The results obtained adopting the riparametrized ECM form (3) refer to the loglinear ADL structures coefficients from which the ECM has been derived. For the demand function, estimates are those of ADL (1,2) form coefficients; the notation recalls what we defined for equation (3).

*Demand function values:*

| Parameter | Estimate | Standard Error | t-statistic |
|---|---|---|---|
| *COST* | 2.08488 | 1.56296 | 1.33393 |
| *alfa 0, PLW* | -0.220062 | 0.200352 | -1.09838 |
| *alfa 1, PLW* | 0.583791 | 0.272148 | 2.14512 |
| *alfa 2, PLW* | -0.236536 | 0.231484 | -1.02183 |
| *D1* | -6.44E-03 | 0.032254 | -0.19958 |
| *D2* | -0.053403 | 0.037389 | -1.42833 |
| *D3* | 0.139559 | 0.035665 | 3.91305 |
| *D4* | -0.015821 | 0.03454 | -0.45804 |
| *D5* | -0.048627 | 0.03197 | -1.52102 |
| *D6* | 0.043197 | 0.026387 | 1.63707 |
| *D7* | 0.0423 | 0.027532 | 1.53637 |
| *D8* | 0.052458 | 0.033901 | 1.54741 |
| *D9* | -0.048904 | 0.033642 | -1.45365 |
| *D10* | 0.08322 | 0.027546 | 3.02112 |
| *D11* | -0.068046 | 0.037434 | -1.81776 |
| *beta 1, GYQ* | -0.319581 | 0.205241 | -1.55710 |
| *alfa 0, GYP* | 1.36739 | 1.14948 | 1.18958 |
| *alfa 1, GYP* | 0.197251 | 0.740598 | 0.26634 |
| *alfa 2, GYP* | -1.77673 | 1.00546 | -1.76708 |
| *alfa 0, IP* | -3.6404 | 1.07457 | -3.38775 |
| *alfa 1, IP* | 0.195487 | 1.57702 | 0.12396 |
| *alfa 2, IP* | 2.92658 | 1.05116 | 2.78414 |
| *alfa 0, CT* | 2.20177 | 0.511864 | 4.30148 |
| *alfa 1, CT* | -0.617748 | 0.495333 | -1.24714 |
| *alfa 2, CT* | -1.25624 | 0.540647 | -2.32359 |

In the table above, the name of parameters (*alfa*) are followed by the lag value applied to the corresponding variable.

*Statistics for equation (4) estimate:*

| | |
|---|---|
| Mean of dependent variable | 0.0006835 |
| Std. dev. of dependent var. | 0.0998120 |
| Sum of squared residuals | 0.4727570 |
| Variance of residuals | 0.0045024 |
| Std. error of regression | 0.067100 |
| R-squared | 0.637810 |

For the industry supply function, values refer to an ADL (1,1) parameters whose coefficients are reported in the table below. Estimates account for residuals autocorrelation, as indicated by Durbin-Watson test, providing to adjust standard errors for autocorrelation in order to have a consistent estimate of the covariance matrix.

*Supply function values:*

| Parameter | Estimate | Standard Error | t-statistic |
|---|---|---|---|
| *COST* | -7.51667 | 0.306322 | -24.5385 |
| *D1* | 0.015306 | 0.010668 | 1.43470 |
| *D2* | 0.019149 | 0.01089 | 1.75841 |
| *D3* | 0.026082 | 0.014009 | 1.86175 |
| *D4* | -3.91E-03 | 0.010565 | -0.36964 |
| *D5* | -4.76E-03 | 9.10E-03 | -0.52277 |
| *D6* | -0.010135 | 0.011107 | -0.91244 |
| *D7* | -0.025565 | 0.010781 | -2.37141 |
| *D8* | -0.035751 | 9.94E-03 | -3.59709 |
| *D9* | -0.037033 | 8.04E-03 | -4.60361 |
| *D10* | -0.014513 | 0.012939 | -1.12164 |
| *D11* | -0.01692 | 0.010177 | -1.66253 |
| *beta 1, GYP* | -0.362479 | 0.039085 | -9.27419 |
| *beta 0, NG* | 0.068947 | 0.099005 | 0.69639 |
| *beta 0, EL* | 0.100668 | 0.20985 | 0.47971 |
| *beta 0, WGY* | 0.934432 | 0.227092 | 4.11477 |
| *beta 1, NG* | -0.093294 | 0.098324 | -0.94884 |
| *beta 1, EL* | 0.163897 | 0.203223 | 0.80648 |
| *beta 1, WGY* | 0.788588 | 0.206563 | 3.81767 |
| *beta 0, DR* | -0.057054 | 0.035297 | -1.61640 |
| *beta 1, DR* | 9.50E-04 | 0.039214 | 0.02423 |
| *beta 0, RESD* | 0.099402 | 0.056395 | 1.76260 |
| *bate 1, RESD* | 4.00E-03 | 0.037648 | 0.10619 |

*Statistics for equation (5) estimate:*

| | |
|---|---|
| Mean of dependent variable | -0.0035908 |
| Std. dev. of dependent var. | 0.022175 |
| Sum of squared residuals | 0.067358 |
| Variance of residuals | 0.0006415 |
| Std. error of regression | 0.025328 |
| R-squared | 0.256827 |

The parameter $\beta_{0,GYQ}$ is not included in the table above since it's implicitly determined by the input price coefficients value; $\beta_{0,\,GYQ} = \left( \frac{1}{\beta_{0,NG} + \beta_{0,EL} + \beta_{0,WGY}} - 1 \right)$, where the sum of the three coefficients indexes returns to scale.

Although we estimated the parameters in industry demand and supply equations through the reparametrized ECM form (3), nevertheless we can explain the econometric test results in terms of standard ECM structure coefficients:

$$\Delta y_t = \mathbf{z}_t \boldsymbol{\alpha} + (\beta_1 - 1)\left(y_{t-1} - \boldsymbol{\lambda}^{\mathrm{T}} \mathbf{x}_{t-1}\right) + \boldsymbol{\gamma}_0^{\mathrm{T}} \Delta \mathbf{x}_t + u_t \qquad (6)$$

which allows to distinguish the long-run form the short-run dynamic. Form (6) makes the error correction term explicit, $(\beta_1 - 1)\left(y_{t-1} - \boldsymbol{\lambda}^{\mathrm{T}} \mathbf{x}_{t-1}\right)$; this term, further than representing the proportion of the resulting (long-run) disequilibrium that is reflected in the short-run dynamic, considers in $\left(y_{t-1} - \boldsymbol{\lambda}^{\mathrm{T}} \mathbf{x}_{t-1}\right)$ the long-run relationship between $y_{t-1}$ and $\mathbf{x}_{t-1}$ through vector $\boldsymbol{\lambda}$. From $\tilde{\boldsymbol{\delta}}$ and $\tilde{\beta}^*$ estimate in equation (3) we can easily derive the estimated long-run coefficients vector $\tilde{\boldsymbol{\lambda}} = -\frac{\tilde{\boldsymbol{\delta}}}{\tilde{\beta}^*}$, since $\boldsymbol{\delta} = -\beta^* \boldsymbol{\lambda}$.

With refer to the corresponding ADL form coefficients, from vector $\boldsymbol{\delta} = [\delta_1 \quad \delta_2 \quad : \quad : \quad \delta_k] = [\gamma_{0,1} + \gamma_{1,1} \quad \gamma_{0,2} + \gamma_{1,2} \quad : \quad : \quad \gamma_{0,k} + \gamma_{1,k}]$ and from parameter $\beta^* = (\beta_1 - 1)$, estimated in (3), we can calculate values for long-run coefficient $\boldsymbol{\lambda}$ in ECM form (6):

$$\boldsymbol{\lambda} \equiv [\lambda_1 \quad \lambda_2 \quad : \quad : \quad \lambda_k] \equiv \left[ \frac{\gamma_{0,1} + \gamma_{1,1}}{1 - \beta_1} \quad \frac{\gamma_{0,2} + \gamma_{1,2}}{1 - \beta_1} \quad : \quad : \quad \frac{\gamma_{0,k} + \gamma_{1,k}}{1 - \beta_1} \right].$$

Tables "1a" and "1b" refer to the ECM structure parameters expressed by (6); the following tables illustrate the results of our empirical analysis. The estimates are respectively for the industry demand and supply functions.

**Table 1a:**

*American gypsum board industry: demand function.*

DEMAND EQUATION -- DEPENDENT VARIABLE: QUANTITY ($\Delta$GYQ).

| **Dynamic** | **Correction factor** $(\beta_1 - 1)$ | **Coefficient in the ECM** | **Product price (Output price)** | **Industrial production** | **Construction (residential & commercial.)** | **Substitute product price.** |
|---|---|---|---|---|---|---|
| Long-run | -0.319<br>(-1.557) | Lambda, $\lambda$ | -0.265 | -1.621 | 1.025 | 0.127 |
| Short-run | | Current: $\gamma_0$ | 1.147<br>(1.275) | -3.640<br>(-3.387) | 2.201<br>(4.301) | -0.220<br>(-1.098) |
| Short-run | | Lagged* (t-1): $\gamma_1$ | -2.013<br>(-2.157) | 2.926<br>(2.784) | -1.256<br>(-2.323) | -0.236<br>(-1.021) |

* If the ECM form comes from an ADL (1, 2) then coefficient $\gamma_1$ will multiply the first-difference $\Delta x_{t-1}$.

FOOTNOTES:

a) The equation has been estimated using instrumental variable technique (IV).

b) Recapitalizations for USG and NGCO occurred respectively in 1988 and 1986.

c) *t* statistics are reported in parentheses.

d) Data are monthly and all series are converted in indices after log transformation. Sample period is form 01/1980 to 12/1990.

e) *Dummy* variables are not reported in the table. All price data are deflated by the wholesale price index.

**Table 1b:**

*American gypsum board industry: supply function.*

SUPPLY EQUATION -- DEPENDENT VARIABLE: PRICE ($\Delta$GYP).

| **Dynamic** | **Correction factor** $(\beta_1 - 1)$ | **Coefficient in the ECM** | **Product quantity (output)** | **Natural gas price** | **Electricity price** | **Wage for sic 3275** | ***Debt ratio*** | **Demand shocks** |
|---|---|---|---|---|---|---|---|---|
| Long-run | -0.362 | Lambda, $\lambda$ | 0.192 | -0.067 | 0.729 | 4.753 | -0.154 | 0.285 |
| | (-9.274) | | | | | | | |
| Short-run | | current.: $\gamma_0$ | -0.094 | 0.068 | 0.100 | 0.934 | -0.057 | 0.099 |
| | | | | (0.696) | (0.479) | (4.114) | (-1.616) | (1.762) |

FOOTNOTE:

a) The equation has been estimated using instrumental variable technique (IV).

b) Recapitalizations for USG and NGCO occurred respectively in 1988 and 1986.

c) *t* statistics are reported in parentheses.

d) Data are monthly and all series are converted in indices after log transformation. Sample period is form 01/1980 to 12/1990.

e) To account for seasonality, *dummy* variables have been introduced in the equation, but are not reported in the table. All price data are deflated by the wholesale price index.

f) The demand shock variable represents the residuals from the demand function estimate.

g) *Debt ratio* is the average industry debt ratio; more precisely, the weighted-average debt-to-market value ratio of firms, weighted by each firm's market share.

As illustrated in both tables, long-run coefficient values $\tilde{\lambda} = -\frac{\tilde{\delta}}{\tilde{\beta}^*}$ are not associated with their respective *t* statistics. As a matter of fact, although we can statistically infer on each *individual* coefficient in equation (3),

$$\Delta y_t = \mathbf{z}_t \boldsymbol{\alpha} + \beta^* y_{t-1} + \boldsymbol{\delta}\mathbf{x}_{t-1} + \boldsymbol{\gamma}_0 \Delta\mathbf{x}_t + \boldsymbol{\gamma}_1 \Delta\mathbf{x}_{t-1} + u_t$$

we can not make any operation which involves simultaneously two or more parameters. Since $\tilde{\lambda} = -\frac{\tilde{\delta}}{\tilde{\beta}^*}$, for example, can not be written as a coefficient of an *I*(0) variable with zero mean, standard theory on asymptotic distribution should not be applied. Therefore, calculating the estimated value of $\tilde{\lambda}$ is correct, but the corresponding *t* statistic value is meaningless.

To test for heteroskedasticity in the two regressions, we applied Breusch-Pagan test to the residuals. The sample test value (significant a the 5% level) suggested to accept the null hypothesis of homoskedasticity of residuals.

From the estimation of equation (5), as indicated by Durbin-Watson test[35], we noticed the presence of autocorrelation of residuals. The estimates, we calculated using TSP, account for autocorrelation providing to adjust the standard errors; this yields to a consistent estimate of the covariance matrix.

Residuals turned out to be normally distributed and multicollinearity seemed not to affect the regressors and instruments matrix in each equation.

Finally, the Engle-Granger AEG test (or *residual-based cointegration test*) was adopted to verify that the *I*(1) variables involved in the regression were cointegrated. For both equations, the AEG test gave positive results.

[35]The test accounts for the stochastic matrix, **X,** of regressors.

## 5.2 The high density polyethylene industry.

Identifying the variables determining quantity and price for the polyethylene industry and referring to the equations system (17) and (18) in section 4, we obtain the specific demand and supply relationships:

- (1) DEMAND:

$$POQ_t = COST + \left(\alpha_{0POP} + \alpha_{0,ALC}\right)POP_t + \left(\alpha_{0,IP}\right)IP_t + \left(\alpha_{0,ALC}\right)ALC_t + \varepsilon_t$$

- (4) SUPPLY:

$$POP_t = COST + \left(\frac{1}{\beta_{0,OIL} + \beta_{0,EL} + \beta_{0,WPO}} - 1\right)POQ_t + \left(\beta_{0,OIL}\right)OIL_t + \left(\beta_{0,EL}\right)EL_t + \left(\beta_{0,WGY}\right)WPO_t$$
$$+\left(\beta_{0,DR}\right)DR_t + \left(\beta_{0,RESD}\right)RESD_t + \nu_t$$

where the zero in $\alpha_{0,*}$ and $\beta_{0,*}$ indexes the lag value applied to the series which the parameters refer to ( $x_{t-0} = x_t$ ). The notation used for the variables in the model is:

(DEPENDENT VARIABLES -- ENDOGENOUS):

$POQ$ = Polyethylene Quantity; $POP$ = Polyethylene Price.

(PROXY VARIABLES FOR DEMAND): $IP$ = Industrial Production.

(SUBSTITUTE PRODUCT PRICE): $ALC$ = Aluminum cans.

(INPUTS PRICE IN PRODUCING PROCESS): $OIL$ = Oil; $EL$ = Electricity; $WPO$ = Wage for Polyethylene (for *SIC* 2821).

(OTHER VARIABLES OF INTEREST): $DR$ = Debt Ratio; $RESD$ = Residuals from Demand.

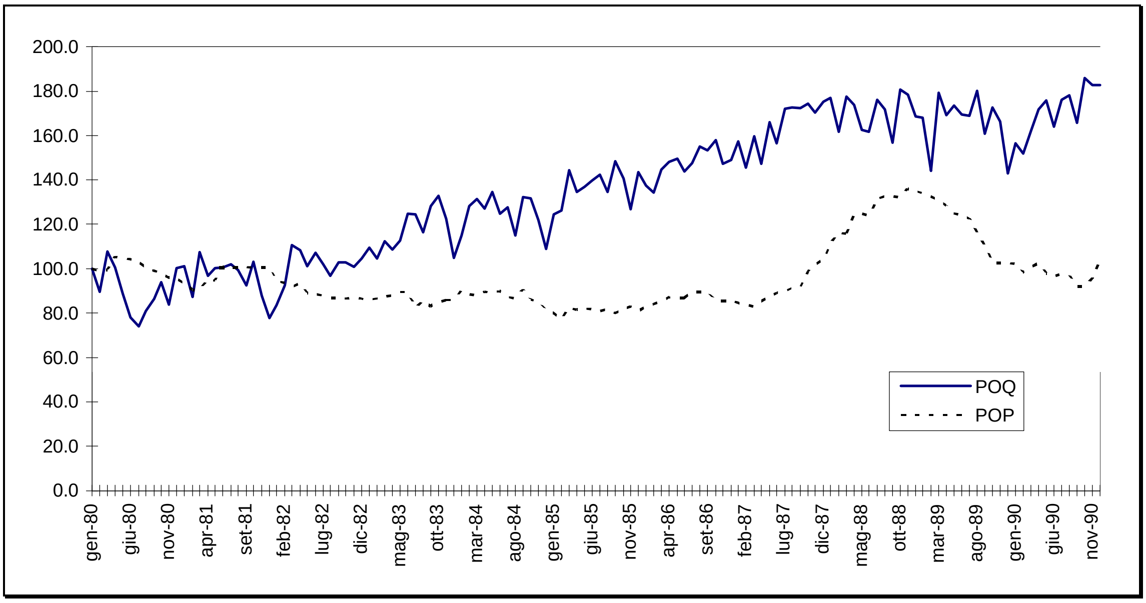
Differently from the gypsum board industry, adopting the riparametrized ECM structure (3) for the polyethylene industry

$$\Delta y_t = \mathbf{z}_t\boldsymbol{\alpha} + \beta^* y_{t-1} + \boldsymbol{\delta}\mathbf{x}_{t-1} + \boldsymbol{\gamma}_0\Delta\mathbf{x}_t + \boldsymbol{\gamma}_1\Delta\mathbf{x}_{t-1} + u_t \,. \qquad (3)$$

did not lead to robust results in estimating the demand and supply relationships. The sophisticated ECM structure turned out not to suit the low short-run variability characterizing the polyethylene price time series (*POP*). The graph below illustrates the absence of variations between sequential periods in the monthly series. Due to this unusual trend, the estimated values from the ECM form overvalued those variations which actually were very small. This problem seems to be the cause of the poor explanatory power we noticed using the ECM structure.

For these reasons we preferred, in order to obtain more reliable estimates, to estimate the two-equations system in its loglinear form.

*Graph 1:* Quantity and price in the polyethylene industry.




Although demand equation (1) did not present such a problem, we estimated equation (1) adopting its loglinear structure to make the estimating process symmetric (for both equations) and to be consistent with the simultaneity of the system.

Adopting the same notation we use for (1), demand equation to be estimated is:

- (4) <u>DEMAND</u>:

$$
\begin{aligned}
POQ_t = COST &+ \sum_{i=1}^{11} \left(\alpha_{D_i}\right) D_i + \left(\alpha_{TREND}\right) T_t \\
&+ \left(\alpha_{0,POP} + \alpha_{0,ALC}\right) POP_t + \left(\alpha_{1,POP} + \alpha_{1,ALC}\right) POP_{t-1} + \left(\alpha_{2,POP} + \alpha_{2,ALC}\right) POP_{t-2} \\
&+ \left(\alpha_{0,IP}\right) IP_t + \left(\alpha_{1,IP}\right) IP_{t-1} + \left(\alpha_{2,IP}\right) IP_{t-2} \\
&+ \left(\alpha_{0,ALC}\right) ALC_t + \left(\alpha_{1,ALC}\right) ALC_{t-1} + \left(\alpha_{2,ALC}\right) ALC_{t-2} + \varepsilon_t
\end{aligned}
$$

The $D_i$ variables are 11 "dummy" variables which account for seasonality in demand and $T$ is a time trend variable.

Differently from what we saw for the ECM structure used in gypsum industry, loglinear form allows us to write the equation exactly as it was estimated in the econometric test and, thus, showing constraints between coefficients explicitly.

For the industry supply relationship the best results were obtained adopting an ADL (2, 2) structure. Referring to the symbols we defined for (2), the supply equation for the polyethylene industry will be as follows:

• (5) SUPPLY:

$$POP_t = COST + \sum_{i=1}^{11}\left(\beta_{D_i}\right)D_i + \left(\beta_{1,POP}\right)POP_{t-1} + \left(\beta_{2,POP}\right)POP_{t-2} + \left(\frac{1}{\beta_{0,OIL}+\beta_{0,EL}+\beta_{0,WPO}} - 1\right)POQ_t$$

$$+\left(\frac{1}{\beta_{1,OIL}+\beta_{1,EL}+\beta_{1,WPO}} - 1\right)POQ_{t-1} + \left(\frac{1}{\beta_{2,OIL}+\beta_{2,EL}+\beta_{2,WPO}} - 1\right)POQ_t$$

$$+\left(\beta_{0,OIL}\right)OIL_t + \left(\beta_{1,OIL}\right)OIL_{t-1} + \left(\beta_{2,OIL}\right)OIL_{t-2} + \left(\beta_{0,EL}\right)EL_t + \left(\beta_{1,EL}\right)EL_{t-1} + \left(\beta_{2,EL}\right)EL_{t-2}$$

$$+\left(\beta_{0,WGY}\right)WPO_t + \left(\beta_{1,WGY}\right)WPO_{t-1} + \left(\beta_{2,WGY}\right)WPO_{t-2}$$

$$+\left(\beta_{0,DR}\right)DR_t + \left(\beta_{1,DR}\right)DR_{t-1} + \left(\beta_{0,RESD}\right)RESD_t + \left(\beta_{1,RESD}\right)RESD_{t-1} + \nu_t$$

where, as in (4), the $D_i$ variable are 11 “dummy” variable.

We estimated the simultaneous two-equations system, here above specified, using TSP 4.1 (*Time Series Processor*) software. Estimating method applied to equations (4) and (5) is the instrumental variable technique (IV).

The table below illustrates the estimates obtained by TSP for the demand function parameters and the respective *t* statistics.

*Demand function values:*

| *Parameter* | Estimate | Standard Error | t-statistic |
|---|---|---|---|
| *COSTA* | 1.97377 | 1.32014 | 1.49513 |
| *TREND* | 5.87E-03 | 7.25E-04 | 8.09899 |
| *D1* | 0.061792 | 0.033752 | 1.83075 |
| *D2* | -2.26E-03 | 0.033717 | -0.06702 |
| *D3* | 0.119695 | 0.035307 | 3.39015 |
| *D4* | 0.058489 | 0.033391 | 1.75166 |
| *D5* | 0.044638 | 0.035208 | 1.26785 |
| *D6* | 0.070241 | 0.033771 | 2.07990 |
| *D7* | 0.059646 | 0.03186 | 1.87213 |
| *D8* | 0.051908 | 0.03292 | 1.57680 |
| *D9* | 0.056227 | 0.033364 | 1.68525 |
| *D10* | 0.124709 | 0.034481 | 3.61678 |
| *D11* | 0.04515 | 0.033195 | 1.36016 |
| *alfa 0,POP* | -0.573102 | 0.980347 | -0.58459 |
| *alfa 0,ALC* | 0.85074 | 0.608011 | 1.39922 |
| *alfa 1,POP* | 1.91234 | 1.90438 | 1.00418 |
| *alfa 1,ALC* | -0.382647 | 0.962413 | -0.39759 |
| *alfa 2,POP* | -1.85463 | 1.13224 | -1.63802 |
| *alfa 2,ALC* | -0.028126 | 0.580155 | -0.04848 |
| *alfa 0,IP* | 2.25199 | 0.955392 | 2.35714 |
| *alfa 1,IP* | 0.464063 | 1.53934 | 0.30146 |
| *alfa 2,IP* | -2.54935 | 0.940727 | -2.70998 |

The name of parameters (*alfa*) are followed by the lag value applied to the corresponding variable.

*Statistics for equation (4) estimate:*

| | |
|---|---|
| Mean of dependent variable | 4.88438 |
| Std. dev. of dependent var. | 0.240494 |
| Sum of squared residuals | 0.554473 |
| Variance of residuals | 0.005181 |
| Std. error of regression | 0.071986 |
| R-squared | 0.925607 |

For the industry supply function, coefficients estimates, in the table below, account for residuals autocorrelation, as indicated by Durbin-Watson test, providing to adjust standard errors for autocorrelation in order to have a consistent estimate of the covariance matrix.

*Supply function values:*

| *Parameter* | Estimate | Standard Error | t-statistic |
|---|---|---|---|
| *COSTB* | -17.3404 | 2.36308 | -7.33806 |
| *D1* | -0.069262 | 0.0375 | -1.84696 |
| *D2* | -0.084171 | 0.040785 | -2.06376 |
| *D3* | -0.064959 | 0.047653 | -1.36318 |
| *D4* | -0.032741 | 0.048441 | -0.67588 |
| *D5* | 0.016722 | 0.03462 | 0.48303 |
| *D7* | 0.01775 | 0.036858 | 0.48156 |
| *D10* | -0.057493 | 0.037768 | -1.52227 |
| *D11* | -0.039785 | 0.052929 | -0.75166 |
| *beta 1,POP* | -0.999308 | 0.732901 | -1.36350 |
| *beta 2,POP* | 2.23677 | 0.747903 | 2.99073 |
| *beta 0,OIL* | 0.126215 | 0.109788 | 1.14963 |
| *beta 0,EL* | -0.967896 | 0.546962 | -1.76959 |
| *beta 0,WPO* | 1.73271 | 0.666743 | 2.59877 |
| *beta 1,OIL* | 0.029496 | 0.16394 | 0.17992 |
| *beta 1,EL* | 0.128324 | 0.705782 | 0.18181 |
| *beta 1,WPO* | 0.893645 | 0.783082 | 1.14119 |
| *beta 2,OIL* | 0.16769 | 0.105327 | 1.59210 |
| *beta 2,EL* | -0.08133 | 0.711874 | -0.11424 |
| *beta 2,WPO* | 1.52311 | 0.734916 | 2.07250 |
| *beta 0,DR* | 0.065088 | 0.109557 | 0.59409 |
| *beta 1,DR* | 0.217345 | 0.123874 | 1.75456 |
| *beta 0,RESD* | -0.489654 | 0.229885 | -2.13000 |
| *beta 0,RESD* | -0.443171 | 0.377699 | -1.17334 |

The name of parameters (*beta*) are followed by the lag value applied to the corresponding variable.

*Statistics for equation (5) estimate:*

| | |
|---|---|
| Mean of dependent variable | 4.55931 |
| Std. dev. of dependent var. | 0.142765 |
| Sum of squared residuals | 0.651318 |
| Variance of residuals | 0.006323 |
| Std. error of regression | 0.079520 |
| R-squared | 0.792313 |

The parameter $\beta_{0,POQ}$ is not included in the table above since it's implicitly determined by the input price coefficients value; $\beta_{*,\,POQ} = \left( \frac{1}{\beta_{*,OIL} + \beta_{*,EL} + \beta_{*,WPO}} - 1 \right)$, where the sum of the three coefficients indexes returns to scale.

To calculate the long-run coefficients, the general rule is:

$\gamma_{\substack{LUNGO \\ PERIODO}} = \frac{\gamma_0 + \gamma_1 + \gamma_2 + \ldots\ldots + \gamma_q}{1 - \beta_1 + \beta_2 + \ldots\ldots + \beta_p}$; which is given by the sum of estimated coefficients of each explanatory variable, divided by 1 less the coefficient (or the sum, if it's necessary) of the lagged dependent variable.

The following tables 2a and 2b illustrate the result of our empirical analysis; estimates and *t* statistics are respectively for the industry demand and supply function.

From the estimation of equation (5), as indicated by Durbin-Watson test[36], we noticed the presence of autocorrelation of residuals. Yet, White test indexes in both the equations. The estimates, we calculated using TSP, account for autocorrelation and heteroskedasticity[37] providing to adjust the standard errors; this yields to a consistent estimate of the covariance matrix.

Residuals turned out to be normally distributed and multicollinearity seemed not to affect the regressors and instruments matrix in each equation.

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[36]The test accounts for the stochastic matrix, **X,** of regressors.

[37]Standard errors are calculated from "*heteroscedastic-consistent*" matrix *(Robust-White).*

**Table 1a:**

*American polyethylene industry: demand function.*

DEMAND EQUATION -- DEPENDENT VARIABLE: QUANTITY (ΔPOQ).

| **Dynamic** | **Coefficient** | **Product price (Output price)** | **Industrial production** | **Substitute product price** |
|---|---|---|---|---|
| Long-run | $\alpha_{LONG\ RUN}$ | -0.075 | 0.166 | 0.439 |
| | | (-12.27) | (20.54) | (3.254) |
| Single period | Current: $\alpha_0$ | -0.573 | 2.251 | 0.850 |
| | | (0.584) | (2.357) | (1.399) |
| Single period | Lagged (t-1): $\alpha_1$ | 1.912 | 0.464 | -0.382 |
| | | (1.004) | (0.301) | (-0.397) |
| Single period | Lagged (t-2): $\alpha_2$ | -1.854 | -2.549 | -0.028 |
| | | (-1.638) | (-2.709) | (-0.048) |

FOOTNOTES:

a) The equation has been estimated using instrumental variable technique (IV).

b) Recapitalizations for Quantum Chemical occurred in 1988.

c) *t* statistics are reported in parentheses.

d) Data are monthly and all series are converted in indices after log transformation. Sample period is form 01/1980 to 12/1990.

e) *Dummy* variables are not reported in the table. All price data are deflated by the wholesale price index.

**Table 1b:**

*American polyethylene industry: supply function.*

SUPPLY EQUATION -- DEPENDENT VARIABLE: PRICE (ΔPOP).

| **Dynamic** | **Coefficient** | **Product quantity (Output)** | **Oil price** | **Electricity price** | **Wage for sic 2821** | ***Debt ratio*** | **Demand shock** |
|---|---|---|---|---|---|---|---|
| Long-run | $\beta_{LONG\ RUN}$ | -0.072 | 0.076 | -0.217 | 0.979 | 0.066 | -0.220 |
| | | | (27.28) | (-1.534) | (3.507) | (15.64) | (-1.977) |
| Single | Current: $\beta_0$ | 0.122 | 0.126 | -0.967 | 1.732 | 0.065 | -0.489 |
| Period | | | (1.149) | (-1.769) | (2.598) | (0.594) | (-2.130) |
| Single | Lagged (t-1): | -0.047 | 0.029 | 0.128 | 0.893 | 0.217 | -0.443 |
| Period | $\beta_1$ | | (0.179) | (0.181) | (1.141) | (1.754) | (-1.173) |

FOOTNOTE:

a) The equation has been estimated using instrumental variable technique (IV).
b) Recapitalizations for QUE (Quantum Chemicl) occurred in 1988.
c) *t* statistics are reported in parentheses.
d) Data are monthly and all series are converted in indices after log transformation. Sample period is form 01/1980 to 12/1990.
e) To account for seasonality, *dummy* variables have been introduced in the equation, but are not reported in the table. All price data are deflated by the wholesale price index.
f) The demand shock variable represents the residuals from the demand function estimate.
g) *Debt ratio* is the average industry debt ratio; more precisely, the weighted-average debt-to-market value ratio of firms, weighted by each firm's market share.

## 6. Conclusions.

The results from estimating the demand and industry supply relationships, illustrated in tables 1a-1b (for the gypsum industry) and 2a-2b (for the polyethylene industry), show that the average industry debt ratio is a significant variable in determining the product price level. As a matter of fact, the more stable conclusion coming from this empirical analysis is that other factors besides input prices and demand shocks are important in explaining product price movements.

With regard to the demand function, the economic theory, in the standard case of a downward-sloping function, predicts the product price to be negatively related to the quantity demanded, while demand shift terms to have a positive coefficient. Parameters estimated in the demand equation, for both industries, are of the correct sign and all are significant. Quantity demanded is negatively correlated to the product price and positively related to the primary substitute product price. Demand shift variables have generally[38] positive coefficients and are always significant.

*The US gypsum board industry*.

In the gypsum board industry we got quite robust results especially considering the error-correction specification we adopted for the estimated equations. In fact, the ECM peculiarity is to split the short-run from the long-run dynamic, linking the variations of the former with the disequilibrium proportions of the latter.
This is where our analysis differs more prominently from Phillips (1995), where a linear model with variables in levels is applied to the same set of industries. But, given the non-stationarity of the majority of the time series involved in his analysis, induced us to estimate the two equations through an ECM in order to tackle the explosive trend of the variables.

The most interesting finding in this industry is the negative correlation between price and debt ratio in the industry supply relationship. The negative sign of the debt ratio coefficient and its significance show that a debt increase, controlling for the effect of input prices and demand shocks, is followed by an output rise and a price fall in the industry.

[38] Just one exception for the parameter on “industrial production” variable in the gypsum board demand, which seems to indicate an anticyclical trend of this variable.

As in Phillips, hence, we have that gypsum board price is negatively associated with the average industry debt ratio.

Concerning the other variables, as illustrated in tables 1a-1b, surprising is the negative sign of the industrial production coefficient which might reflect an anti-cyclical behavior of the product. A similar relation is present also in Phillips (1995) between the variable “shipments of manufactures” (not available to us) and quantity in the demand function.

Differently from Phillips (1995), is consistent with the economic theory the positive sign of the coefficient of the primary substitute product we estimated in the demand equation. Also, in contrast with Phillips, the demand-shift variable in the supply function displays a positive sign; this is consistent with some theoretical work in the field (Green and Porter, 1984) predicting a positive correlation between price and demand shocks. As in Phillips (1995) one of the input prices has negative coefficient.

The positive relationship between debt and output can be justified in the light of some peculiarities of the industry, namely: (a) entry barriers are low because the production technology is simple with small plant size relative to the size of the market. In addition, (b) the companies with the smaller market share (relative to those recapitalized) have low financial leverage.

The increase in output following a debt rise, as we have found in the gypsum board industry, is consistent with those theoretical models (Brander-Lewis, Maksimovic) which link riskier production strategies, and the associated output increase, with a high financial leverage.

These results are inconsistent with the “deep purse” theory (Bolton-Scharfstein, Poitevin) which, in this case, predicts predatory behavior by rival firms with a low debt ratio. However, it is more reasonable to think that the previous theory should be adapted to a different scenario, where companies with a low financial leverage *and* a larger market share are more aggressive towards rivals that are financially constrained *and* with a lower or equal production capacity.

*The polyethylene industry.*

The results from estimating the demand and supply equations in this industry confirm the sensitivity of financial structure changes’ effects to variations of variables characterizing the scenario where firms strategically interact.

In fact, in the polyethylene industry, in contrast with what we saw for the gypsum board industry, the average debt ratio is positively correlated to the product price in the industry supply relationship. The positive coefficient of the average industry debt ratio (*DR*) and its significance show that a debt increase, controlling for the effect of the other factors on price, is followed by an industry output decrease.

The findings from estimating the demand equation are similar to Philips (1995) but quite different are the estimates of parameters in the supply relationship, with the exception of the debt ratio coefficient which is of positive sign as I found in our analysis. The most significant differences deal with values of the three input prices' parameters; in Phillips (1995) it's surprising to find that all the three coefficients have negative sign, difficult to explain according to the firms' profit maximization behavior predicted by the economic theory. Differently, our estimation gives positive coefficients for all the input prices, with the only exception of electricity price.

The negative relationship between debt and output, resulting from the econometric test applied to the polyethylene industry, where rival firms have high financial leverage and entry is relatively difficult, is consistent with the hypothesis that firms which increase their financial leverage commit to decrease in output and discretionary expenditures. As firms restrict free cash flow, fewer funds are available to spend on capacity expansion, advertising and other investments.

The results we obtained for the polyethylene industry confirm, hence, what Glazer (1989) and Phillips (1992) predict in their theoretical models in which capital structure affects product markets and particularly output decisions of firms and their rivals because it can act as a credible commitment not to exercise investment opportunities and to behave "less aggressively".

While this paper does suggest that the nature of competition, in oligopolistic markets, changes when firms' financial structure changes, the different conclusions coming from the empirical test applied to the two industries do not necessarily make any contribution to the debate concerning whether a higher debt ratio has to be associated with a predatory rather than a collusive behavior by firms competing in the same industry. Thus, scope for further work could be focusing on the "quality" of debt held by the companies, given their debt ratios. Glazer's theoretical model (1989) seems to suggest a "theory of *entry for debt*"[39] due to the dynamic effects of long-term debt on product decisions. Given the difference between "long-term" and "short-term" debt as defined by Glazer (1989), it would be interesting to test, through an econometric model,

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[39]The terminology recalls the article of D. Fudemberg and J. Tirole, "*A Theory of Exit in Duopoly*" (Econometrica, 1986). Here, the term "*entry*" wants to highlight how *time of issuing* long-term debt, taking into account the maturity date of debt issued by competitors, can be considered as a strategic variable for the firm.

whether debt affects product strategies not only by the extent to which it changes firm's debt ratio but also by the extent to which firm's debt repayment plan differs (with refer to the quantity and the maturity date of debt) from its rivals' ones.

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