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PETROL POLICY IN COLOMBIA: CHALLENGES AND OPPORTUNITIES

By

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September 1999

DECLARATION OF OWN WORK

I declare that this thesis:

"Petrol policy in Colombia: challenges and opportunities"

is entirely my own work and that where any material could be construed as the work of others, it is fully cited and referenced, and with appropriate acknowledgement given.

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TABLE OF CONTENT

1. INTRODUCTION 1

1.1. BACKGROUND 1
1.2. GENERAL AIMS 2
1.3. QUESTION TO ANSWER 3
1.4. PROCEDURE 3
1.5. ASSUMPTIONS 5
1.6. STRUCTURE OF THE REPORT 7

2. FUEL SUPPLY IN COLOMBIA 8

2.1. FUEL FLOW: IMPORTS, REFINING, CONSUMPTION 8
2.2. REFINING AND ECOPETROL 9
2.2.1. Worldwide Economics of Refining Trends 9
2.2.2. Ecopetrol and the Colombian Refining Industry 14
2.3. TRENDS IN PETROL DEMAND 17
2.3.1. Quantity 17
2.3.2. Quality 19
2.4. SUPPLYING PETROL 21
2.5. PETROL PRICING 21
2.6. ENVIRONMENTAL ISSUES IN PETROL SUPPLY 26

3. INSTITUTIONAL AND POLITICAL ANALYSIS 31

3.1. ECOPETROL AS A MONOPOLY VERTICALLY INTEGRATED 31
3.2. FREE MARKET IN PETROL SUPPLY TO COLOMBIA 35
3.3. STRATEGIC ALLIANCES AND JOINT VENTURES 37
3.4. INTERNATIONAL OUTLOOK 38
3.4.1. Venezuela 38
3.4.2. Brazil 39
3.4.3. Mexico 41
3.4.4. Argentina 42
3.4.5. China 43
3.4.6. Indonesia 44
3.4.7. Other Countries 45
3.5. INSTITUTIONAL AND LEGAL FRAMEWORK REQUIRED FOR A FREE MARKET IN COLOMBIA 46

4. ECONOMIC ASSESSMENT OF ALTERNATIVE SCHEMES 50

4.1. PREVIOUS APPLICATIONS OF LINEAR PROGRAMMING IN THE OIL INDUSTRY 50
4.2. AIMS 52
4.3. QUESTIONS TO BE ANSWERED FROM THE LP MODEL 52
4.4. INPUT VARIABLES 52
4.4.1. Demand of petrol in the Barrancabermeja refinery in the year 2010 52
4.4.4. Functions for the Barrancabermeja expansion and the Pozos Colorados – Galan importing pipeline 55
4.5. CONSTRAINTS 63
4.6. OBJECTIVE FUNCTION AND THE ALGORITHM 63
4.7. RESULTS 65

5. ANALYSIS AND DISCUSSION 70

5.1. INSTITUTIONAL, POLITICAL, TECHNICAL, ECONOMIC AND ENVIRONMENTAL ISSUES 70
5.1.1. Quality of petrol 70
5.1.2. Quantity of petrol 72
5.1.3. Tackling petrol smuggling 73
5.1.4. Petrol pricing 75
5.1.5. Reliability of petrol supply 76
5.1.6. Reliability of petrol supply: Petrol imports vs. Petrol refined within Colombia 77
5.1.7. Economy of Ecopetrol refining 78
5.1.8. The link between good management and reaching Benchmarking targets 79
5.1.9. Macroeconomic considerations 80

5.1.10. SELF-SUFFICIENCY IN PETROL SUPPLY VS. SELF-SUFFICIENCY IN OIL SUPPLY 81
5.1.11. Trade off between importing costs and level of efficiency of Ecopetrol 82
5.1.12. How Ecopetrol and the country may benefit from losing market share due to competition? 83
5.1.13. Why wholesalers might be interested in importing their own petrol? 83
5.1.14. Institutional and political strategy for Ecopetrol 84
5.1.15. How to deal with the trade union USO 85
5.1.16. Environmental and social aspects 85
5.2. LP MODEL RESULT: CHARACTERIZATION OF EACH OF THE THREE SCHEMES 87
5.2.1 Scheme 1 Expanding Refining Capacity 87
5.2.2. Scheme 2 Expanding Petrol Importing Capacity 90
5.2.3 Scheme 3 Combination of Both 92

6. CONCLUSIONS AND RECOMMENDATIONS 94

6.1. OVERALL CRITICAL DISCUSSION OF THE MERITS AND DRAWBACKS OF THE STUDY 96
6.2. TOPICS REQUIRING FURTHER STUDY 97

7. REFERENCES 98

APPENDIX 1: WORLD FUEL CONSUMPTION 101

APPENDIX 2: REFINERY CAPACITIES AND THROUGHPUTS 102

APPENDIX 3: REFINING MARGINS AND PROFITABILITY 103

APPENDIX 4: THREE SCENARIOS OF PETROL DEMAND IN COLOMBIA 1999 - 2010 104

APPENDIX 5: THE POZOS COLORADOS – GALAN PETROL IMPORTING PIPELINE 105

APPENDIX 6: COLOMBIAN OIL AND PETROL PIPELINE GRID 106

TABLE OF TABLES

TABLE 1: PETROL QUALITY TARGETS IN COLOMBIA……....20

TABLE 2: FUELS QUALITY IN EUROPE……20

TABLE 3: PETROL DEMAND OF THE BARRANCABERMEJA REFINERY IN 2010…...……53

TABLE 4: ECOPETROL STRUCTURE OF REFINING MARGIN……...……...…53

TABLE 4A: RETURN OF CAPITAL IN THE BARRANCABERMEJA REFINERY PERFORMANCE……56

TABLE 5: LP MODEL - RESULTS SHEET – THE BARRANCABERMEJA REFINERY……...……..…68

TABLE 6: NET MARGINS OF MAIN ECOPETROL PRODUCTS 1998 COLOMBIAN CURRENCY……..……..…. 79

TABLE OF GRAPHS

GRAPH 1: FORECAST OF PETROL DEMAND GROWTH IN COLOMBIA…….18

GRAPH 2: TRENDS OF REGULAR PETROL PRICES IN COLOMBIA……..……25

GRAPH 3: NEW PETROL PRICE STRUCTURE…….…26

GRAPH 4: EXPANSION CAPACITY OF THE POZOS COLORADOS – GALAN PETROL IMPORTING PIPELINE…….……57

GRAPH 5: EXPANSION OF CRACKING AND DISTILLATION CAPACITIY IN THE BARRANCABERMEJA REFINERY……61

GRAPH 6: SHARE OF REFINED PETROL AS FUNCTION OF IMPORTED AND REFINED PETROL PRICES – LOW SCENARIO……...…….65

GRAPH 7: SHARE OF REFINED PETROL AS FUNCTION OF IMPORTED AND REFINED PETROL PRICES – ECOPETROL SCENARIO……..66

GRAPH 8: SHARE OF REFINED PETROL AS FUNCTION OF IMPORTED AND REFINED PETROL PRICES – HIGH SCENARIO……..…….67

GRAPH 9: SENSITIVITY ANALYSIS OF PETROL PRICES: COSTS OF REFINING vs. COSTS OF IMPORTING……..……69

GRAPH 10: TRADE-OFF OF THE OPTIMUM PETROL QUALITY……..……...…70

GRAPH 11: OPTIMUM EXPENDITURE LEVEL FOR CONTROLING PETROL SMUGGLING……..……..…..74

TABLE OF DIAGRAMS

DIAGRAM 1: FUEL FLOW IN COLOMBIA……..……..8

DIAGRAM 2: ADDED VALUE IN THE OIL INDUSTRY AND REFINING MARGIN……...…….….11

DIAGRAM 3: COMPARISON OF CONVERSION LEVELS BETWEEN THE COLOMBIAN REFINERIES AND THE BENCHMARK……...….15

DIAGRAM 4: TYPICAL REFINING MARGIN OF ECOPETROL IN COMPARISON TO THE BENCHMARK……...…..16

DIAGRAM 5: THE PETROL CHAIN IN COLOMBIA……...…….…….23

DIAGRAM 6: PETROL MARGIN: REFINED vs. IMPORTED……....55

DIAGRAM 7: SCHEMATICS OF THE PETROL PRODUCTION PROCESS IN THE BARRANCABERMEJA REFINERY……..……..58

DIAGRAM 8: PRICE DIFFERENTIAL IN LOW SCENARIO: INCREASE ONLY IN REFINING……..……...…….88

DIAGRAM 9: PRICE DIFFERENTIAL IN ECOPETROL SCENARIO: INCREASE ONLY IN REFINING……...…..89

DIAGRAM 10: PRICE DIFFERENTIAL IN LOW SCENARIO: INCREASE ONLY IN IMPORTATION……..91

DIAGRAM 11: PRICE DIFFERENTIAL IN ECOPETROL SCENARIO: INCREASE ONLY IN IMPORTATION……91

1. INTRODUCTION

1.1. Background

In Colombia it is evident that the state-ruled companies have not been efficiently managed. There have been a lot of projects in electricity generation, road building, maritime ports, and the Medellin underground for which final costs and the period of building exceeded their initial budgets by several times. Most of the reasons are attributed to mismanagement, lack of planning, short sight and many other ill effects of a very unstable and fluctuating policy making.

Since the late 80's the government has been undertaking measures to open the economy and encourage private investment as a result of a world trend to improve the efficiency of the state by concentrating its efforts in a few activities. In this way, the state can deliver fewer but better services and the private sector can provide the rest of the services with a better management of resources. Consequently, the state can be released from the burden of becoming heavily indebted in hard currency to fund capital intensive projects of a fast growing infrastructure demand.

In Colombia the petrol supply sector lags well behind other sectors such as the electricity supply, ports, and motorways, in undertaking an open policy. However, freeing the petrol supply market is considered necessary in order to release the state from the economic burden that it would otherwise have. There is absolutely no doubt about the fact that the government will not get as much funds as it might need for expanding its infrastructure unless it brings in private capital. This will involve a trade off between borrowing money and giving the investment responsibility to private companies. The government therefore has to make decisions to settle a new legal and institutional framework in order to send the appropriate signs to encourage participation of the private sector.

This situation is particularly true in the oil industry, which is one of the most capital-intensive businesses. Within this industry, the upstream is the most capital intensive with the highest risks and therefore the most profitable. The downstream is less capital intensive, less risky and, indeed, much less profitable. That makes the downstream projects low in their return of capital, hence, a business that should be run with a long-term perspective.

Because of budgetary shortages of the Colombian Oil Company (Ecopetrol) and a commitment of the state to reduce fiscal deficit in order to make the economy more stable, the government has planned to create a framework for freeing market using private companies. Thus, it wants ultimately to create a mature free market to supply petrol at every stage of the commercial chain from upstream to downstream thereby improving efficiency and competitiveness.

There are five refineries in Colombia with 79% of petrol supplied by two of them, 20% imported and the rest just supplying 1%. Petrol importers use the Pozos Colorados (Santa Marta) – Galan (Barrancabermeja) pipeline, from the north coast to the main refinery in the centre of the country. Ecopetrol, the state-owned oil company, has a monopoly in most of the stages of the fuel supply such as refining, transporting and importing. In addition, four private companies Esso, Mobil, Texaco and Terpel are the wholesalers. Likewise, there are roughly 2000 private retailers that buy petrol from the four wholesalers, using their brand names.

The main purpose of the present thesis is to make an assessment of the petrol supply chain in Colombia identifying the key driving factors, the companies involved and the challenges they are facing in the light of world and regional trends. In addition, the thesis will assess what is the best trade off between importing and/or refining for supplying petrol to Colombia regarding three different schemes under three different scenarios of demand. Furthermore, it will offer a critical analysis of the measures that the government has taken forecasting possible outcomes. And finally, in the light of world trends and the Colombian own situation, the thesis aims to conclude with an agenda of recommendations to the Colombian government to tackle future petrol supply challenges.

1.2. General Aims

- To assess the current situation, identify and suggest solutions for the problems facing petrol supply in Colombia from the technical, institutional, environmental, financial and political point of view.

- To assess critically the current measures that are being undertaking by the government to tackle economic inefficiency and lack of competitiveness in the petrol supply chain.

- To make recommendations to policy makers about the measures that have to be taken in order to get the cheapest petrol either from refining or from importing looking at a deregulated market in the long term. In addition, making recommendations to policy makers looking at futures challenges of the oil industry. Amongst these are: improving the quality of petrol to meet stricter environmental regulations; reducing operational costs to be alive in a paper thin margin business; and how to scale up the business to take advantage of economy of scale and remain competitive in the market in the long run.

1.3. Question to Answer

- Should the Colombian Oil Company expand its refining capacity to become petrol self-sufficient? Should it expand petrol-importing capacity to buy it from abroad? More broadly, what should it do to obtain the cheapest petrol considering economic, social, technical, environmental, institutional and financial issues?

1.4. Procedure

- Information collected at Imperial College (IC) London and at the Oxford Institute for Energy Studies (OIES) Oxford

- Information collected in Bogota, National Planning Department, Colombian Oil Company (Ecopetrol)

- Interviews:

    - Vice-president of Refining and Marketing, former Manager of the Cartagena refinery, Ecopetrol. Jose Luis Saavedra

- Esso Colombia Ltd., one of the only four wholesaler. Daniel Barragan
- Director of the Energy and Mines division of the National Planning Department, Alvaro Balcazar
- Engineer in charge of Ecopetrol issues at the National Planning Department, Daisy Cerquera
- Engineer of Process Industrial Modeling System (PIMS) Ecopetrol, Carlos Guzman
- Economist who works in the international marketing, Ecopetrol, Luis Roberto Cabrera
- Coordinator of operations, Barrancaermeja refinery, Ecopetrol, Pablo Motta
- Economist who works in the Gas and Energy Regulating Commission, former researcher of OIES Oxford, Fernando Barrera Rey
- Vice-presidency of Transport – Ecopetrol. Fernando Gonzalez
- Researcher at Oxford Institute for Energy Studies (OIES) Oxford, Paul Horsnell

- Assessing the current situation

  - Refineries: main technical characteristics, products, level of conversion, efficiency, operating costs, current operations, investment plans
  - Pipelines, in particular, the importing pipeline Pozos Colorados - Galan. The former located at Santa Marta by the coastline, and the latter located nearby Barrancabermeja refinery in the centre of Colombia. Current operation, main technical characteristics, investment plans, transport fees
  - New petrol price structure. To avoid inflationary pressures and heavy subsidies. Problems generated by petrol smuggling from Venezuela and how to tackle it
  - Ecopetrol at a crossroad: Very low explorations rate (23 wells per annum) which is threatening oil self-sufficiency by 2006. The focus must therefore be on the upstream rather than on the downstream.
  - Assessing development plans for refineries and pipelines
  - Estimating petrol demand under different scenarios: switching from petrol-fueled to both diesel-fueled and compressed natural gas engines, modernization of cars that justify switching from regular petrol-fueled engines to extra petrol-fueled engines (with higher octane number)
  - Quality of petrol to follow Euro II regulation

- LP Model for economic analysis.

  - Using Excel and including linear and step functions to analyze the technical constraints and economics of the refining, foreign market and importing processes, there will be a model to obtain the optimum amount of petrol to be refined and imported. These will be compared for certain scenarios of prices, rates of return of marginal investments in expansions and petrol demand.

1.5. Assumptions

- This work only deals with petrol. The critical product in the refining industry in Colombia, as in general everywhere, is petrol. Colombia has surpluses of middle distillates such as Jet, Kerosene and Diesel, which are exported. In the same way, there are large amounts of fuel oil that are exported. Therefore, the critical component from the economic and technical point of view is petrol. In addition, most of these surpluses are shipped to the coast through the Magdalena River. Thus, only the pipeline is used for petrol imports.

- The work does not include the small refineries. There are three small refineries that supply 1% of the petrol consumption put together. They are isolated and designed to meet local demand, hence, they do not exchange anything abroad. There is no infrastructure to do so.

- The LP model takes into account only the Barrancabermeja refinery. Although the Cartagena refinery supplies nearly 20% of the national petrol consumption, it is designed to meet regional demand (Caribbean coast). Furthermore, it is located on the coastline and is a low conversion refinery with old machinery. It is widely accepted that unless there is heavy investment in updating it technologically as well as considering a special added value due to potential petrochemicals developments, the refinery might not be viable in the long run if facing international competition. Additionally, the fact that the Barrancabermeja refinery is located in the centre of the country makes it very competitive in relation to the foreign market. Petrol demand in

Bogota accounts for almost 50% of the whole national consumption. In this way, the dilemma of whether to import or to refine has to be centered on the Barrancabermeja refinery.

- The Cartagena refinery is almost completely independent of the Barrancabermeja refinery. In practice there is some exchange of naphtas and other oil-products but this is not crucially important to make decisions about whether to expand refining capacity or expand the pipeline Pozos Colorados – Galan for imports.

- For this analysis the petrochemical industry is not considered in the LP model. The principal focus of this dissertation is petrol supply. There is no space for speculations about reaching the state of self-sufficiency in petrochemicals. Although a high rate of demand of petrochemicals is expected from now onward, Colombia's demand is very low at the moment by international standards. And this demand can be met from the market with a high reliability.

- The critical pipeline for importing is the Pozos Colorados – Galan. No other pipeline of the grid is considered here because investment plans should be the same whether petrol is refined in Barrancabermeja (Galan) or imported.

- Constant oil assay of the oil mixes in the throughput of the Barrancabermeja refinery. It is assumed that the physical and chemical composition including the API grade of the oil mix will not change in the next 11 years. In the real world, it is very likely that such a change might in fact happen affecting the share of products of refinery.

- The LP model assumes perfect competition and availability of petrol storage facilities. In order to run the model, it is necessary to assume perfect competition with foreign companies and that issue related to petrol storage is sorted out. That means storage tanks already built in the Barrancabermeja refinery to store petrol imported. In reality, this issue has not been solved yet, and it is technically necessary to allow petrol to be imported.

1.6. Structure of the report

Chapters 1 gives an introduction to the main issues related to the petrol supply in Colombia in order to provide the background for the problem to be tackled. The problem is identified. The second part of the chapter describes the general objectives of the theses giving details about the questions the research will be looking to answer.

Chapter 2 presents a description of the petrol supply in Colombia including fuel flow and trends in the demand and quality. In addition, the current new structure of petrol pricing in Colombia is described highlighting potential problems in the foreseeable future.

Chapter 3 identifies the institutional issues surrounding petrol supply in Colombia, in particular its state-owned company Ecopetrol. There is also information about what other state-owned companies are doing internationally. And finally there is a discussion about what should be Ecopetrol's fate, what sort of lessons may be applied from other's experiences.

Chapter 4 gives an economic assessment of alternative schemes. The LP model is used to assess the alternatives to expansion to meet petrol demand up to ten years now. It contains the aims, the questions to be answered by the LP model, the constraints and the results.

Chapter 5 contains a discussion of the main issues concerning the future of petrol supply in Colombia looking at the environmental, economic, institutional and political issues as well as the results from the model.

Chapter 6 offers some concluding remarks together with recommendations to the Colombian government.

Lastly, chapters 7 and 8 are the appendix and references respectively.

2. FUEL SUPPLY IN COLOMBIA

2.1. Fuel flow: imports, refining, consumption

The following diagram depicts the fuel flow in Colombia. As it is shown, 65% of the Colombian oil production is exported, and only the remaining 35% is used to meet the national fuel demand. The figure (1) are in thousand of barrels per day.

FUEL FLOW IN COLOMBIA

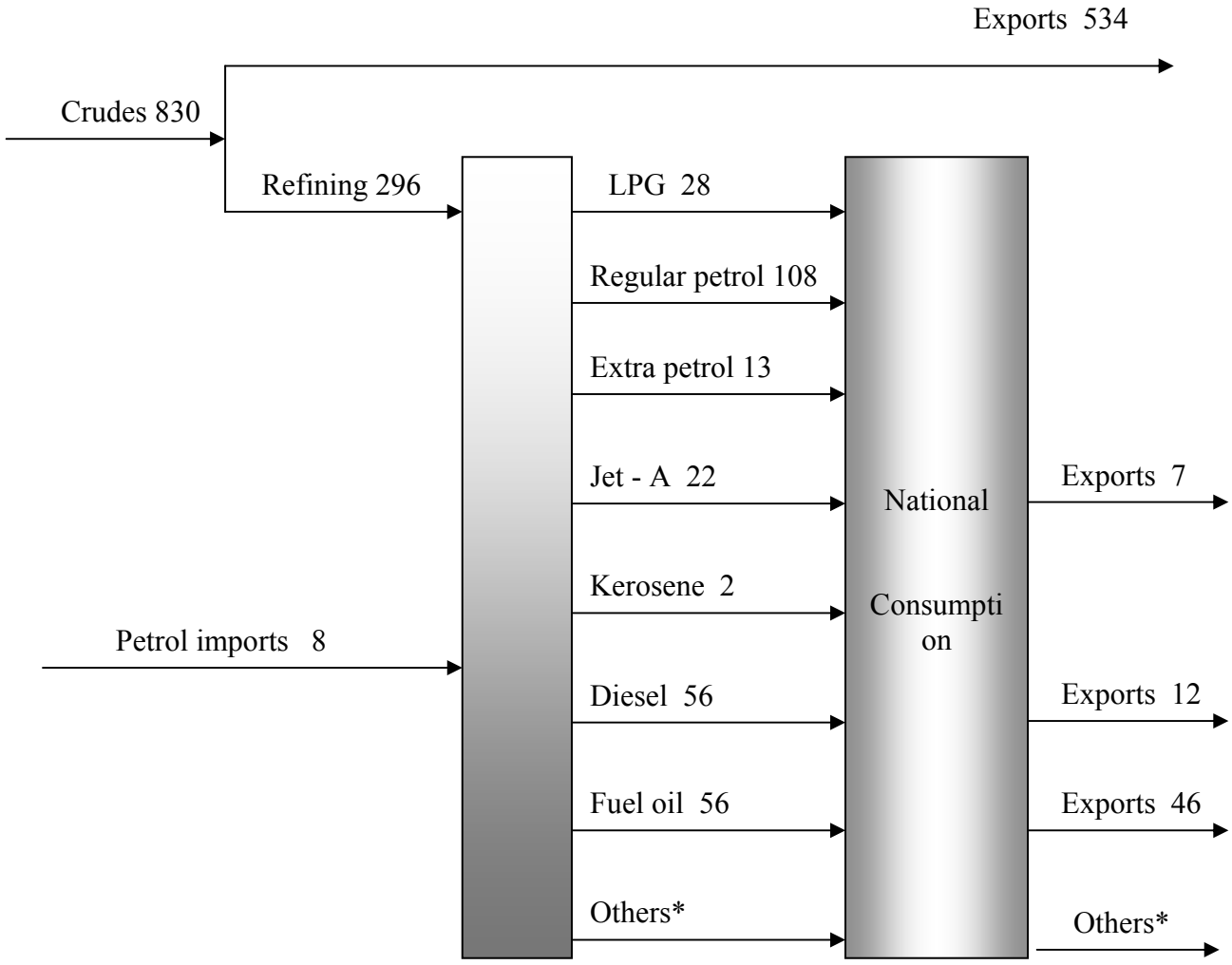


DIAGRAM 1

* Internal consumption: Olefins 3, Asphalt 3, and Petrochemicals 2
  Exports: Light fuel oil 5, strait run naphta 3

Source: Optimum PIMS run, August 1999 – January 2000, ECOPETROL

From the above diagram, it is also important to highlight that Colombia has surpluses of middle distillates and heavy fuel oil. By contrast, there are petrol imports to meet internal demand. The reason can be seen in Diagram 1 because in Colombia there is a low conversion refining capacity and therefore is unable to produce lighter products.

Other important aspect that stresses the technological lag in the refining industry of Colombia is the fact that, although there are surpluses of petrol naphta from distillation, there are petrol imports. The reason is that the refining industry in Colombia does not have the technology to produce high-octane petrol, 94 Research Octane Number (Ron) petrol, which is called extra petrol in the common market. Consequently, the Colombian Oil Company (Ecopetrol) has to import 98-Ron petrol, and then blend it with lower octane petrol in order to get 94-Ron petrol, or extra petrol.

2.2. Refining and Ecopetrol

2.2.1. Worldwide Economics of Refining Trends

The world has had a gradual growth of primary energy consumption in the last decades with smooth fluctuations. There are many factors that affect energy demand, but amongst the most important are economic growth, energy efficiency and the weather. The 1997/98 warm winter, the economic meltdown of Asia and the emerging markets are blamed for the decline in last years world primary energy consumption from 8483 Million Tones Oil Equivalent (MTOE) in 1997 to 8477 MTOE in 1998 (2). Oil has had the greatest share in world primary energy consumption at around 42%, and it is expected to remain as the most important energy source for at least the next 20 years. It has been asserted by the most respected forecasters like the Energy Information Administration (EIA) of the US Department of Energy, and the International Energy Agency (IEA). Oil is the largest commodity traded internationally in both physical volume and turnover.

Oil substituted coal as the major world energy source late in the nineteenth century. Then, it was a business ruled by seven competitors that in the 1950s were called the

seven sisters. That reign ceased in the seventies with the Organization of Petroleum Exporting Countries (OPEC), the first oil crises in 1973 when the Libyan leader took control on his oil fields, and the second oil crises in 1979 with the deposition of the US supported Shah in Iran. Since, there has been an explosion of developments in the oil industry worldwide creating a very mature market constituted by many companies and a few of them enormously powerful. New technologies were developed enabling them to explore for more oil from deeper underground both inland and offshore. At the same time, the decrease in freight fares and new infrastructure in ports and pipelines are boosting international trade.

These technological and institutional achievements have not only occurred in the upstream oil industry, exploration and exploitation, but also in the downstream business, refining and distribution. What countries consume is not oil straight, or crude, but products obtained from oil refining. Thus, there has been a huge technological progress in trying on the one hand, to take more products from a barrel and on the other hand, to improve lighter products with high added value.

The need to extract more light products from a barrel arises because as a country develops, it requires more fuels for the transport sector. As income rises, trade increases, the number of motorcars and planes augment, and therefore, more transport fuels like petrol and diesel are needed. Consequently, refineries are forced to adequate its product slate to meet demand avoiding unnecessary surpluses of cheap products.

Taking into account the above concepts, it can be seen in the Appendix 1 how different the fuel demand patterns in various areas of the world are. For instance, in Europe and North America, about 70% of the demand of refined products are petrol and middle distillates. Whereas, in the Asia Pacific and other parts of the world, they consume less light products in proportion to fuel oils that are used for electricity generation and marine transport. This has an impact on their refineries. They need to be of higher conversion in developed countries than in developing countries. Needless to say about stricter environmental regulation in the former countries than in the latter. In other words, refineries need more technology in rich countries than in poorer due to differences in the pattern of demand.

In Diagram 2 it is depicted the typical average added value in the oil industry from upstream to downstream activities. As can be seen, the greatest share of the final

ADDED VALUE IN THE OIL INDUSTRY AND REFINING MARGIN

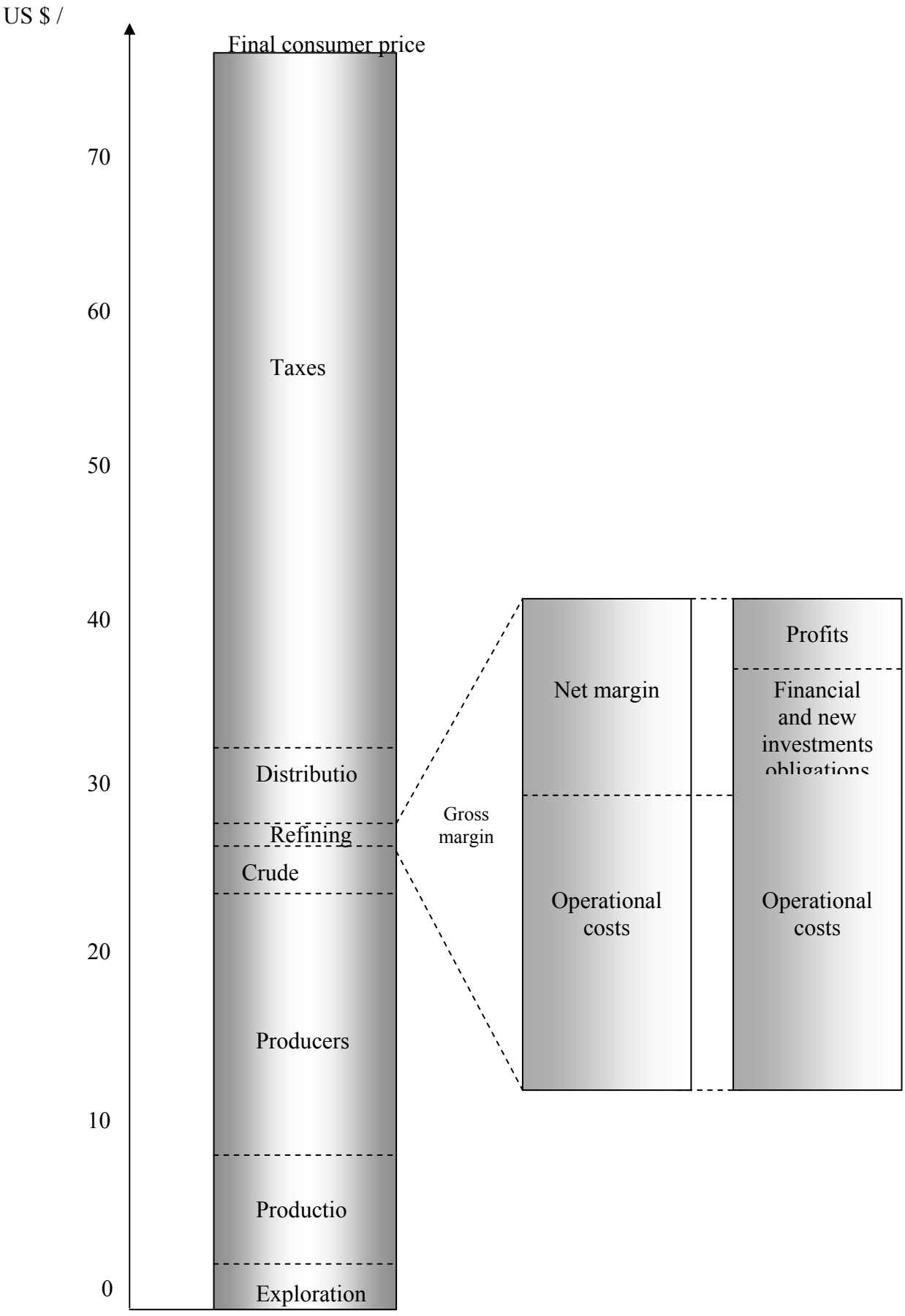


DIAGRAMA 2 Source: (53)

consumer price goes to governments, whereas, refineries get the thinnest share. Likewise, it is clear that the refining process is a business of margins, thus, profitability depends upon the difference between the price products are sold, the cost of the raw materials, which are mostly crudes, and the operating and financial costs. As it can be observed in Diagram 2 the refining industry is highly vulnerable to fluctuations in its production costs. It might bring a refinery from making profits to losses rapidly if there are changes in transport fares, labour costs or financial commitments.

Looking at these issues in a worldwide basis, why the refining sector has suffered from shrinking margins over the last decades and what are the challenges they will face in the foreseeable future? First of all there are historical reasons to explain that. Building refineries require long periods of time, which means that it is necessary to forecast several years in advance. In the seventies, western forecasters were very optimistic of growth in oil-related product demand and they were afraid of facing lack of supplies, which could halt the economy of a nation. However, things have happened differently causing forecasters to fail in predicting two major world trends: the environmental concern and the improvements in efficiency on both the refiners and the consumer appliances.

This has affected refineries in two main different ways. On one hand, there was a sharp increase in the building of refineries, which caused a significant overcapacity since the seventies; that means, there were major investments and financial burdens for standby capacity, or 'capacity creep'. As can be seen in Appendix 2, although the world trend has been consistent within the last 15 years, regions have had different trends. For instance, in mature markets with availability of technology and investment capacity; i.e., Europe and North America, the difference between refining capacity and throughputs has lessened. As a result, capacity utilization has increased in order to improve profitability and adjust the economy of refining to the paper-thin margins. Today, the 702 refineries in the world have a refinery capacity utilization of about 84% (7).

On the other hand, with the world moving away from heavy fuels and growing increasingly hungry for cleaner transport fuels, production costs have been ever increasing. It has caused the net refining margin to shrink to unprofitable levels, as depicted in Appendix 3, for some of the most important refineries. In the time span of nearly 20 years there were several occasions in which refineries not only did not make

any profit at all, but losses. Accordingly, during 1997, incremental cracking margins languished between 1 to 2 dollars per barrel in the world's main refining centres, the US Gulf Coast, Rotterdam and Singapore. Such margins generate cash returns on investment of 2 to 5%, a far cry from target values of up to 15% (3). To make matters worse, closing down refineries can be an even worse business than running refineries in unprofitable conditions due to the environmental costs associated to the cleaning up of the site. It could be in the order of US$100 million according to an article written by Andrew Wishart in the Oxford Energy Forum magazine (3).

The prospect for a recovery of refining margins is really dark. Multinationals like BP Amoco and Shell have announced plans for selling a significant share of their global refining capacity. According to Sir John Browne, chief executive of BP Amoco, "our general expectation now is that the global refining margin will average little more than US$1 a barrel, over the medium term compared to nearer US$2 for the past five years"(4). In the same way, margins on the US Gulf Coast have been around US$1 per barrel for 10 years save for two years when they were about US$2 a barrel (5). Moreover, in mature markets refining is returning about 6-8% on capital employed, compared to 12-15% for marketing, which has been boosted by selling convenience goods like drinks and chocolate. Likewise, the industry is expecting to face huge capital expenditure in the near future to meet more stringent environmental standards for its refined products, for instance, in Europe that figure is around US$20 billion for the next five years.

Additionally, there are other reasons why some of the refiners are not optimistic about the future. Compared with other industries, the refining sector is not very concentrated and this intensifies competition. Shell and Exxon, the world's leading refiners, together control slightly above 10% of the world capacity. In the US for instance, the largest two companies control 80% in soft drinks, 70% in beer, 60% in car, 40% in airlines and as little as 13% in refining (6).

After this pessimistic overview of oil refining it is important to see the positive side of the coin. What can be see as hope to the refining industry?

Most of the refining capacity was built in the seventies not only to meet an optimistic growing demand, as mentioned before, but for a standard type of crude that was then

average heavier than today's. As time went on, this standard has shifted toward a better quality of feedstock due to new discoveries of light, low sulphur crudes. Despite this, refiners have had to carry on using heavy crudes because their refineries had already been designed for that kind of feedstock. As a result, it has decreased the price differentials between heavy/light and sweet (low sulphur) / sour (high sulphur) crudes, thereby making it relatively cheaper for refiners to switch feedstock than to invest in new facilities to process lighter crudes.

Furthermore, increased transparency of markets has led to product globalization with traders quickly capitalizing on spot market opportunities. Similarly, low shipping rates have made it possible to move cargo long distances to take advantage of price differentials. Apart from that, there is a faster growing demand for petrochemicals in developing countries that would justify joint projects and improve margins. Lastly, there are several options to reduce operational costs, such as introducing co-generation to reduce energy costs and automatization to increase efficiency and reduce labour costs.

2.2.2. Ecopetrol and the Colombian Refining Industry

Total primary energy consumption in Colombia is very low in comparison to the Latin American and the world average. It accounts for 5.2 Barrels Oil Equivalent (BOE) per capita, whereas the Latin American and the world average are 6.3 and 10.7 BOE per capita respectively (8). The share of the Colombian primary energy sources are 50% oil, 25% wood, 12% hydroelectricity and 6% natural gas and growth of the demand is expected to be about 3.4% for the period 1998-2010. Also, oil and natural gas are expected to become 52.5% and 8.9% of the primary energy demand in the same period at the expense of wood, according to forecast of the Mining and Energy Planning Unit. Consequently, growths in the oil derivative demand of about 3.6%, 2.6% for petrol, 4.9% middle distillates and 4.4% for LPG is predicted. However, it is forecast that the demand for fuel oil will remain constant.

National consumption of refined products was 267 Thousand Barrels per Day (TBD) in 1997, of which petrol consumption accounted 131 TBD. Refinery capacity in Colombia, currently, is 317 TBD with two main refineries: The 220 TBD Barrancabermeja refinery that represents 70% of the national capacity, the 76 TBD Cartagena refinery and other

four mini refineries that account for 20 TBD altogether. These mini-refineries meet local demands, as does the Cartagena refinery. Thus, the crucial refinery is Barrancabermeja, not only because of its size, but also crucial because of its geographic location in the centre of the country which gives it a very important competitive advantage.

The Colombian refineries are considerably outdated from the technological and operational viewpoint in comparison to the average refineries in a developed country. According to a benchmarking assessment of the Colombian refineries, carried out by Solomon Associates Inc, energy consumption is 175%, well above 100% of the benchmark. The maintenance index, which is maintenance costs per barrel of distillation capacity installed, is 203%, and labour costs in operation is 147% that of the benchmark (9). In addition, the conversion level of the Colombian refineries is lower than the benchmark, as can be seen in Diagram 3 where conversion level is 79% and the benchmark is 92%. This means that from the same feedstock pattern, a refinery in

COMPARISON BETWEEN CONVERSION LEVELS OF THE COLOMBIAN REFINERIES AND BENCHMARK

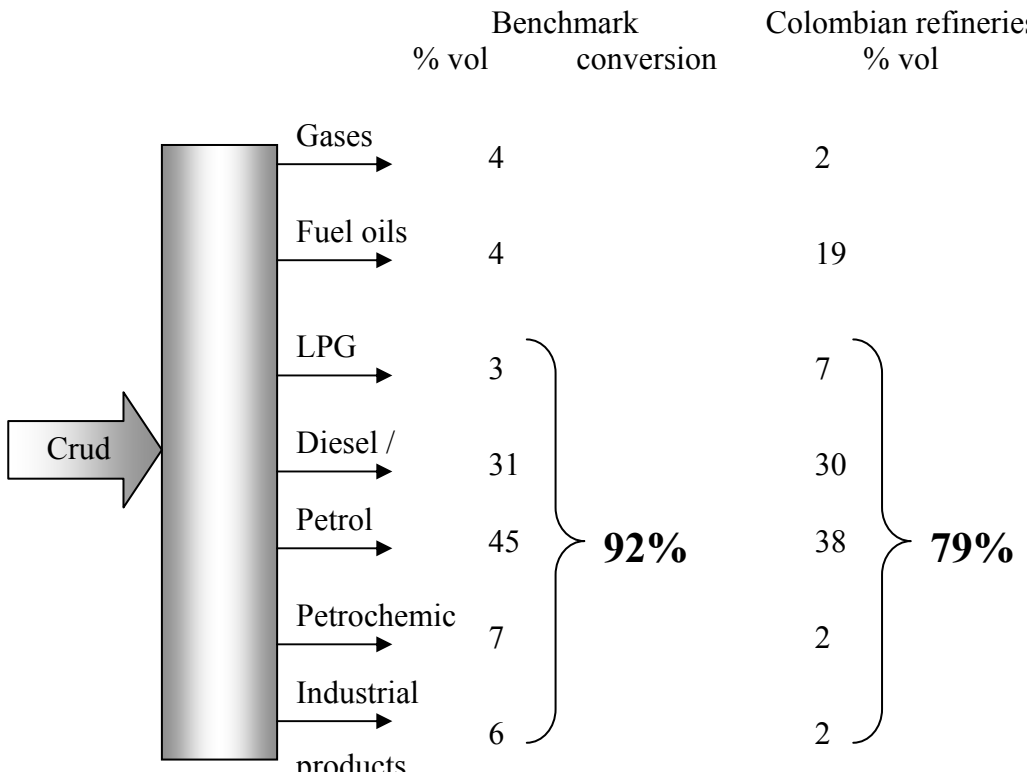


DIAGRAM 3 Source: (9)

Colombia can extract less valuable products from a barrel than its benchmark equivalent. Hence, a Colombian refinery produces more fuel oil whereas an updated refinery can produce more petrol, diesel, petrochemicals and industrial products instead of fuel oils.

The conversion level of a refinery directly affects its own economy. The higher the level of conversion, the wider the gross margin. The reason is very simple, a higher conversion level means that the refinery can obtain high revenues from selling its products, therefore, there is a wider gap between the price of its crude and its average product price. For instance, the average gross margin for the benchmark is US$ 5.2 per barrel, whilst the average gross margin for a Colombian refinery is US$ 3.0 (10). Diagram 4 illustrates the real average situation between Ecopetrol's refinery margins and the benchmark. The latter making a smaller profit whereas the former results in losses.

TYPICAL REFINING MARGIN OF ECOPETROL IN COMPARISON TO A BENCHMARK

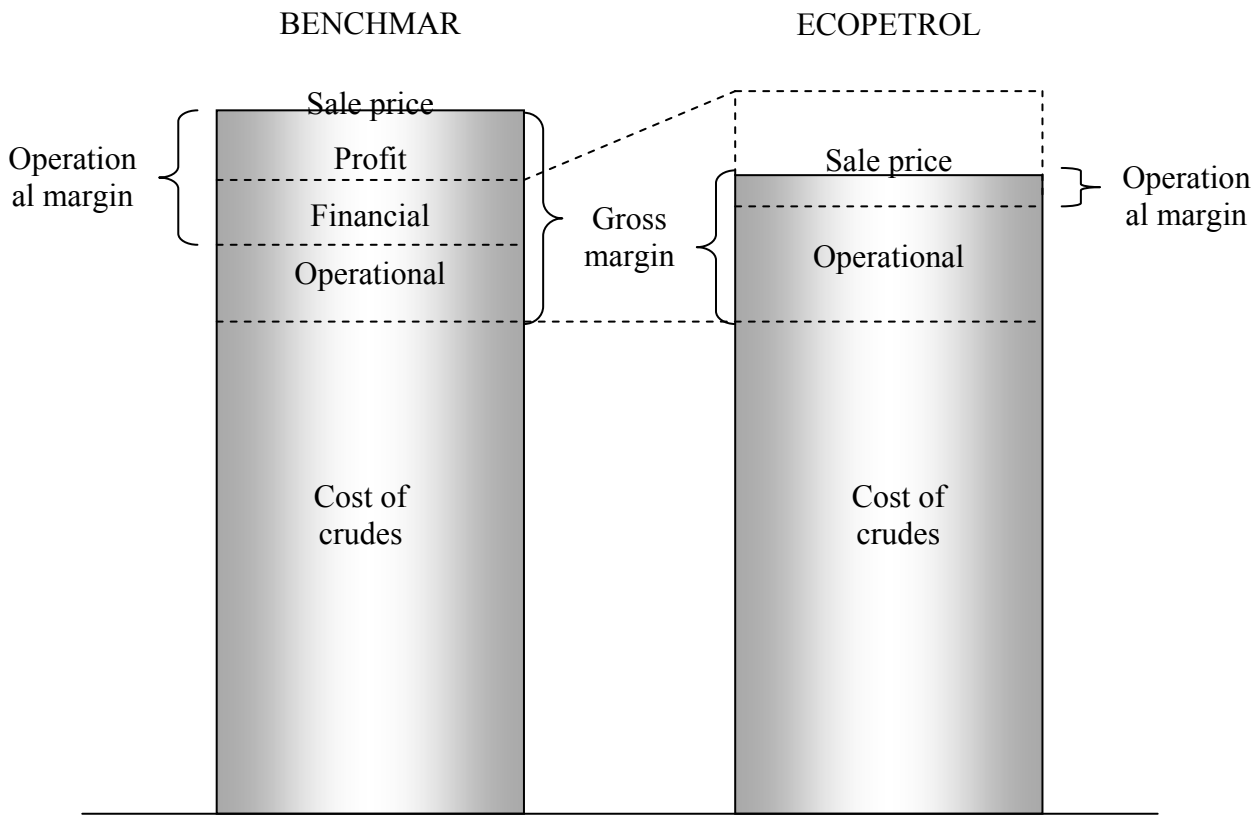


DIAGRAM 4 Source: author

This means that although Ecopetrol's operational margin in refining is positive, its financial obligations are greater than the margin, thus, Ecopetrol actually loses money in its refining business. It is consequence of a US$1.4 billion debt attributed to Ecopetrol refining (9). Indeed, 90% of such debt is due to pension liabilities.

Furthermore, Ecopetrol's high operational costs are due to excessive energy consumption, overstaffing and processing inefficiency, without taking into account the lack of automation in Ecopetrol's refineries. Thus, Ecopetrol's operating cost is US$1.4 per barrel higher that the benchmark's.

Another important feature of Ecopetrol's refineries is a relatively low utilization level in comparison to the benchmarks. For instance, in 1996 and 1998 it was of 75% and 75.9% respectively, therefore it is significantly below the benchmark's 85% utilization level. The causes being related to the weaknesses in operating efficiently and mismanagement as discussed above.

2.3. Trends in petrol demand

2.3.1. Quantity

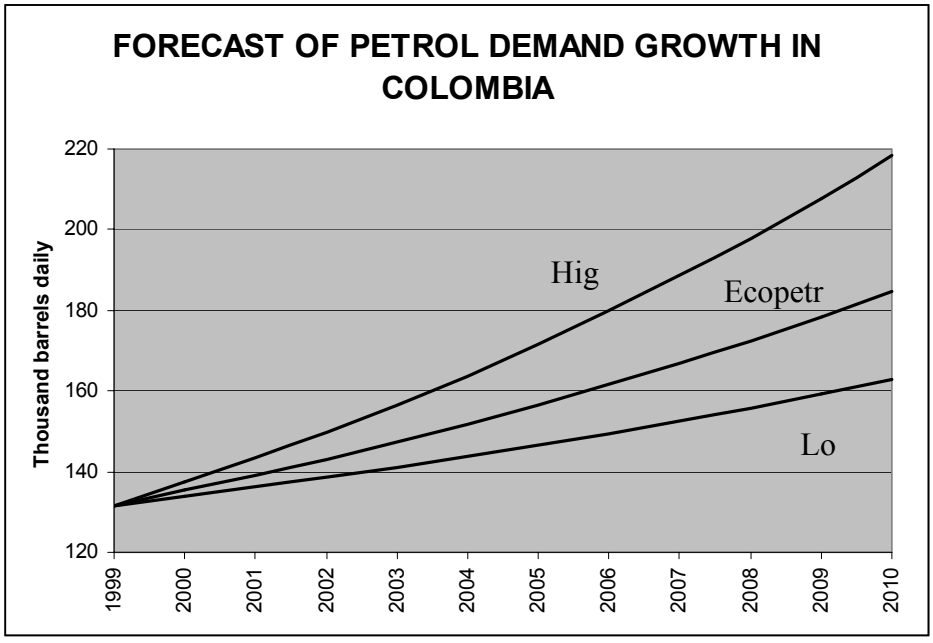
Growth in petrol demand depends mostly upon growth in income per capita, changes in pricing and alternative fuel's pricing. Weighting them, income per capita has the most influence on demand, whilst alternative fuel's pricing such as diesel and natural gas prices comes second. There have been quite a lot of studies assessing the responsiveness of petrol demand to changes in income per capita and petrol prices worldwide (11). Overall, these studies have led to more or less the same conclusions. That is that petrol demand is elastic to changes in income per-capita, and the increase is larger in the long run than in the short run. By contrast, petrol demand is relatively inelastic to price changes, both in the long and short terms, with the former a bit higher than the latter (12)

In Colombia petrol demand grew at a constant 4% per annum for decades, then five years ago it slowed down as a result of 'dieselization' (switching from petrol to diesel) of heavy transport and improvement in motorcars efficiency attributed to electronic injection. Last year there was a breakthrough, for the first time ever petrol demand in

Colombia decreased. This has been blamed on the booming of injection in motorcars (higher efficiency), which grew at an astonishing 15% last year (13), and the measures that were taken in Bogota to restrict private transport twice a week in order to improve traffic.

Electronic injection causes petrol consumption to decrease because efficiency improves. Thus, there is less petrol consumption per mile, and therefore less demand. In fact, normally, there is a switch in demand from regular petrol to extra petrol. This is because most of the injection motors have a volumetric compression ratio higher than 9.5, and it requires high-octane petrol, thus, motorcar drivers switch the petrol quality as they update their motorcars.

Looking at these issues, three different scenarios of petrol demand until the year 2010 will be considered. Firstly, a high scenario regarding high-income per-capita as well as low substitution by alternative fuels (diesel, natural gas). Secondly, an intermediate scenario according to Ecopetrol forecast (10) of 2.6% until 2010. Lastly, a scenario of low income per-capita and high switching towards natural gas and diesel. Hence, in the last scenario it is assumed that the 'Transmilenio' project of switching to natural gas vehicular for the massive transport in Bogota will succeed. As it can be observed in Graph 1, the new



GRAPH 1

amount of petrol that should be found to meet demand until 2010 are 31, 53, and 87 TBD according to the three scenarios of demand. The supplies can be met by either expanding the refinery capacity, expanding the importing pipeline to buy it from abroad, or a shared solution.

2.3.2. Quality

In spite of major improvements in the characteristics of the most traded fuels in Colombia, petrol and diesel, they are still below European or US standards. In 1991 Ecopetrol refineries phased out lead as an octane enhancer from petrol. Likewise, in 1994 and 1996 octane number enhanced in regular petrol from 82 to 86 RON and in extra petrol from 92 to 94 RON. Also, in 1996 sulphur content was reduced from 0.15 to 0.10 per cent in weight these fuels.

However, in 1995 the government planned new targets for petrol quality improvements in the Resolution 898 after an agreed commitment, between Ecopetrol and the Ministry of Environment, however there are concerns of achieving those targets nowadays. It would imply heavy investment in equipment for the refineries that so far has not been undertaken for lack of resources. The most relevant item, of the nearly US$450 million required, is a desulphurising plant. Additionally, the project may last between 3 to 5 years and being committed to reach targets by 2001 it has not started yet.

As it can be seen in Table 1 and Table 2, the most important difference between the European petrol and the Colombian is the sulphur content. Today's European sulphur content is a target to achieve by 2006 in the Colombian case. In the same way, diesel has a higher Cetane Index in Europe, which means European diesel is better anti-detonant, therefore it resists higher volumetric compression ratios without igniting out of the right time (14). Likewise, the Colombian petrol, both regular and extra, have lower octane number that the US petrol. It is 94 and 98 RON in the US whereas it is 86 and 94 RON respectively in Colombia. Contrary, the aromatic and benzene content in the Colombian petrol are lower than the European, making petrol more environmental friendly in that

particular parameter. Aromatics are regarded as poisonous and carcinogenic when taken in large doses.

PETROL QUALITY TARGETS IN COLOMBIA

Parameter	Unit	January 1996	January 2001	January 2006
PETROL				
Octane Regular	RON	86	86	86
Octane Extra	RON	94	94	94
RVP (max)	Psia	8.5	8.1	8.1
Sulphur (max)	ppm	1000	500	300
Oxigen (min)	% weight	-	2.0	2.0
Aromatics (max)	% volume	28.0	25.0	25.0
Benzene (max)	% volume	1.1	1.0	1.0
DIESEL				
Sulphur (max)	Ppm	4000	1000	500
Aromatics	% volume	20	20	20
Cetane Index	Index	45	45	45

Source: Resolution No 898, August 23rt 1995

TABLE 1

FUELS QUALITY IN EUROPE

	Unit	Present	2000 (Euro 3)	2005 (Euro 4)
PETROL				
Sulphur	ppm	500	150	50
Benzene	%	5	1	not agreed yet
Aromatic	%	-	40	35
RVP	Kpa	-	60	not agreed yet
DIESEL				
Sulphur	ppm	500	350	50
Cetane Index	Index	49	51	not agreed yet

Source: Petroleum Review May 1999

TABLE 2

There are three main reasons why it is important to carry on improving petrol quality in the Colombian refining. First, there will be health damage such as respiratory diseases due to less harmful emissions. Second, it would encourage efficiency in all the motorcars allowing entrance of the latest motorcars to the national market without technological barriers. In this way, the country can have access to more efficient technologies from the economic, technical and environmental point of view. Third, making the pace of fuel

quality improvements regionally can bring goodwill, market opportunities and can save a lot of money in the future.

2.4. Supplying petrol

Ecopetrol has been the only petrol supplier in Colombia. Such responsibility amongst other social tasks was given when Ecopetrol was founded as the state-owned oil company. However, this company has had to import roughly 20% on the national demand in order to reach extra petrol quality as the refineries can not reach that octane number. Hence, Ecopetrol supplies around 80% of the 130 TBD that is today's demand.

Ecopetrol sells the petrol to four wholesaler, Esso, Mobil, Texaco and Terpel. They distribute petrol to the nearly 2000 petrol stations spread in the country. Each petrol station is committed to buy petrol from just one wholesaler and uses its brand. There is only one producer, a monopoly, four wholesalers with no real competition, and around 2000 retailers in intensive competition since petrol price liberation in January 1999.

2.5. Petrol pricing

Petrol price in Colombia used to be fixed every December by the government until a few years ago. It was blamed for inflationary pressures that resulted in sharp price increases over all sectors. Because of that, the last government decided not to increase petrol prices once in December as it used to, but to do it gradually during the year looking to break the link between inflation and petrol price increases. Moreover, the state attributed a social orientated vision to Ecopetrol rather than an economic guided corporation. It resulted in heavy subsidies for every product from kerosene to extra petrol. Ecopetrol was obligated to sell petrol at a much lower price than the international, there have been calculations which assert that this difference prevented Ecopetrol from revenues of about US$500 million yearly for at least 10 years. Additionally, these subsidies did not benefit most of the citizens because in a very unequal society like the Colombian, only the minority of the population owns and uses cars.

Taking into account these problems and the juncture of parity for the first time ever between national and international petrol prices to avoid social disturbances, the government issued the Resolution 8 2438 on the 23rd of December 1998 to free petrol prices. However, it was not a total freedom, there are three different regimes. Watched freedom, which allow retailers in big cities to change their margins in order to forge competition. Regulated freedom in many small towns and rural areas where there can not be competition, thus, the retailing margin is fixed. And lastly, total regulation for especial areas like islands and remote towns in the amazon wild and the eastern valleys. In these places the new petrol pricing structure is neglected and Ecopetrol carry on supplying petrol at subsidized prices.

Amongst the most relevant characteristics of the new petrol pricing structure is the unification of the municipality tax that ceased disruptions in the petrol market because of its differences among neighbouring municipalities. Also, there was a unification of charges for additives and evaporation losses. Likewise, the Mining and Energy Planning Unit was assigned to updating the petrol prices structure on a monthly basis. Overall, it was set a fairer framework for the petrol market in Colombia, on one hand allowing the market forces to interact in every suitable place, and on the other hand protecting other areas where it is required to do so.

Diagram 5 shows the petrol chain in Colombia. The upper line depicts the physical flow beginning in the refinery, then passing through the wholesalers' storage tanks, the petrol station until it reaches the motorcar. The middle line illustrates the market participants, refiners or importers, wholesalers, retailers and consumers. The last line, shows the composition of the petrol pricing structure linked to the market participants.

As can be seen in Diagram 5, although fifteen variables affect the petrol price, only two of them are completely independent. The US petrol price of the US Gulf Coast and the exchange rate to translate such price into 'pesos colombianos', the Colombian currency. That is why the petrol price in Colombia has been tighten to the international prices. The other variables are the operating costs and the profits of the wholesalers and retailers, transporting fares and the numerous different taxes.

THE PETROL CHAIN IN COLOMBIA

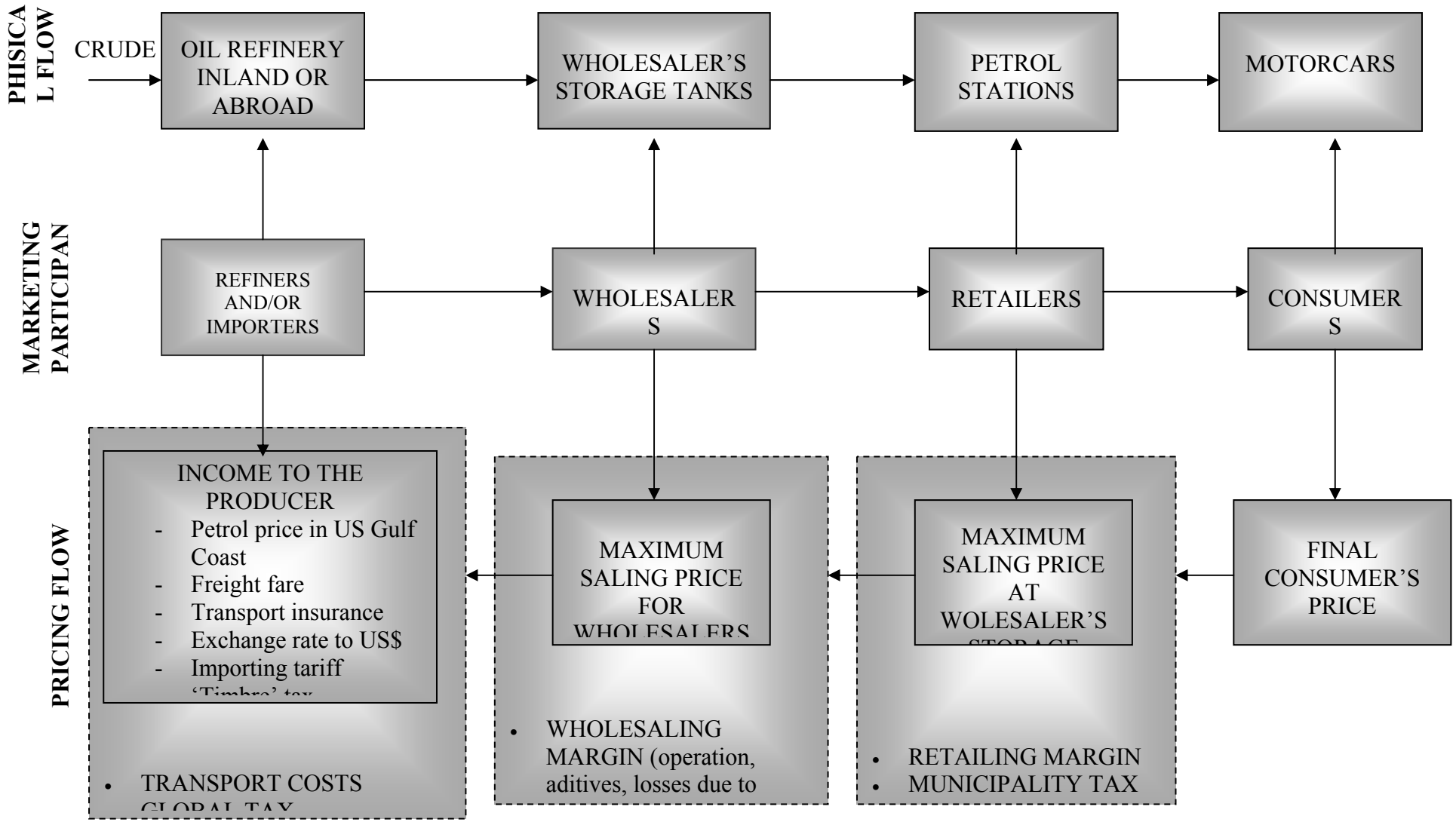
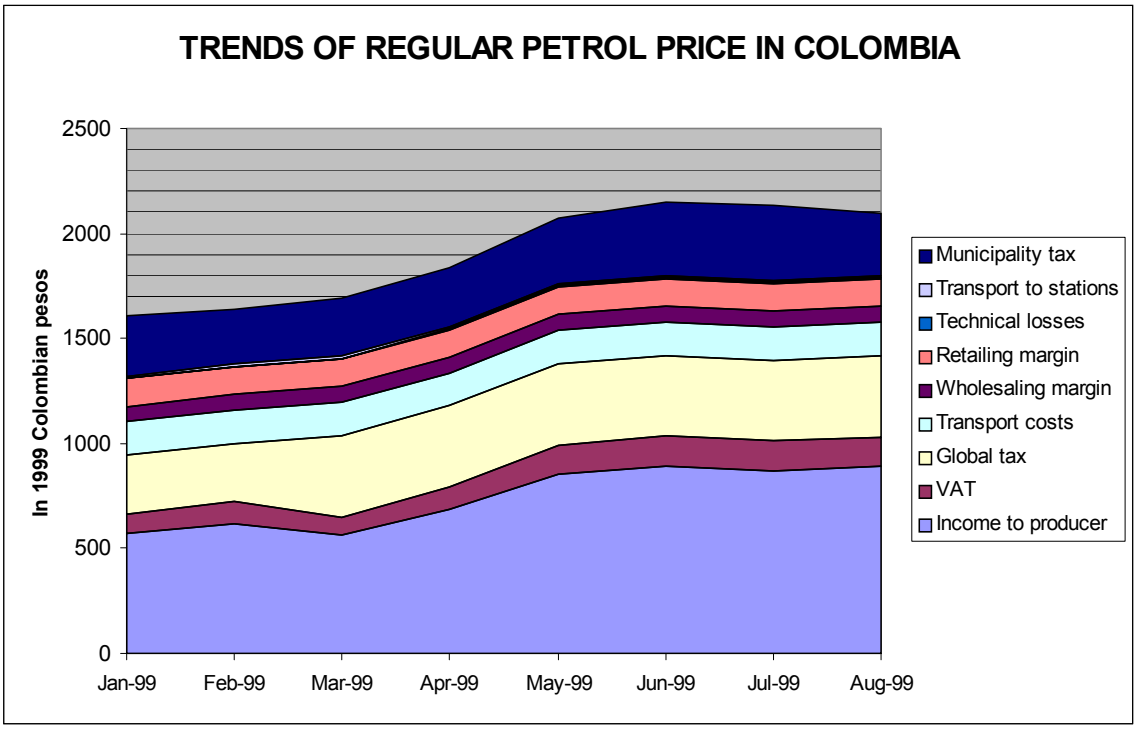


DIAGRAM 5

Unfortunately it has been impossible for the government to maintain that new pricing structure. The reason is that the two independent variables have increased sharply due to a 100% rise in the oil price and 20 per cent devaluation in the Colombian peso. It caused a 33 per cent increase in petrol price which could not be sustained (15).

The government has had to change its pricing formula twice to avoid further increases. First, it reduced the importing tariff from 15 to 7.5%, and second, the government decided to calculate the exchange rate from the last three months average instead of the day before calculating the price for the next month. It curbed the petrol prices for August of the current year, as can be seen in Graph 2. Thus, sometimes a very good intention for

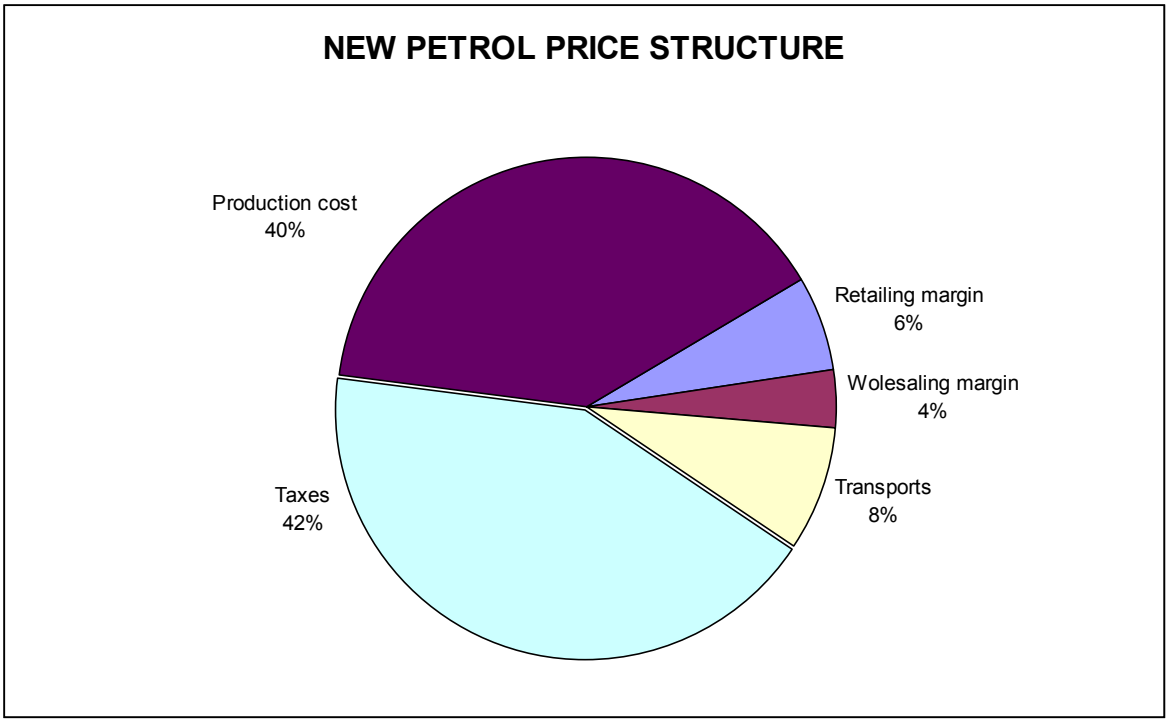


GRAPH 2

petrol pricing may not be practicable due to, on one hand, the macroeconomics volatility that can result in wide fluctuations of the exchange rate in days. On the other hand, the social sensitivity of a low-income nation that may not be able to cope with wide fluctuations of prices. This is even worse when taken into account that transport in Colombia depends almost entirely on motorcars unlike other countries which rely on railways or shipping to transport massive and heavy goods.

It is important to notice that the watched regime that allows free competition in the big Colombian cities can only be reflected in changes in the retailing margin, which represent 6% of the whole price as can be observed in Graph 3. The rest of margins depicted in Graph 2 are fixed for every station.

In spite of the increases in petrol prices in Colombia, it is still cheaper than prices in others countries. The main reason for that is the taxing policy. For instance, in the UK about 85% of the consumer's price are taxes, in the US it is about 50%, whilst in Colombia it is around 40% as can be seen in Graph 3.



GRAPH 3

Likewise, petrol price is higher in countries like Paraguay, Chile, Peru, Brazil, Argentina and Uruguay. Unfortunately, the price of petrol is cheaper in Colombia's neighbours (16). This has triggered uncontrollable petrol smuggling to Colombia that according to Ecopetrol's figure accounts for about 10% of today's national consumption or 13 TBD (17).

Smuggling is causing economic losses to Ecopetrol, the nation and the municipalities due to less revenues from petrol taxes, as well as a reduction in petrol quality because the

Venezuelan petrol is still leaded unlike the Colombian. For instance, in the Department of North of Santander, which is by the Venezuelan frontier, only 35000 gallons are being bought legally out of 495000 gallons per month of consumption (18).

2.6. Environmental issues in petrol supply

There is environmental pollution in each of the petrol supply links, port, pipeline, refining, and retailing. Leakage into the sea when unloading from ships during petrol importing occur affecting flora and fauna. Then, as petrol is stored in Pozos Colorados station, located at Santa Marta in the north coast of Colombia, there is leakage which pollute land and groundwater. At the same time, there is air pollution as Volatile Organic Compounds (VOC) are released. Some of them are carcinogenic when inhaled in large quantities and emits horrible odours, which can be smelt on the motorway communicating the Santa Marta city with the centre and west of the country.

In petrol transport the environmental impact is even worse than in the port and the Pozos Colorados station. The reason is mainly attributed to illegal perforation of the petrol pipeline grid. In particular the Pozos Colorados – Galan pipeline that is currently used for petrol importing. The authorities have discovered 'petrol cartels' who perforate the pipelines to steal petrol and then sell it to retailers illegally. In the same way, the leakage occur due to lack of maintenance, errors in designing and building, and technical leakage in joints and pumping stations. Indeed, the Pozos Colorados-Galan pipeline is pretty heterogeneous. Hence, there are spans of 12, 14 and 16 inches of diametre with pipes made of different material that result in different capacities. Consequently, there are leakage permanently that pollutes water streams, groundwater, land, flora and fauna.

Currently, there has been a great deal of environmental concern because of petrol smuggling. As mentioned in previous chapters, today's petrol smuggling account for roughly 10 per cent of petrol national consumption (13 TBD). The most important environmental problem is that almost all the petrol that has been imported comes from Venezuela, and it is leaded petrol. As a result, the citizens are harmed both, in their health because lead poissoning has associated with brain diseases, and in their motorcars because the electronic injection engines working life is shortened. The other important issue is that the smuggling chain is entirely unfriendly environmentally. Petrol is

manipulated with no appropriate equipment causing leakage during the loading and unloading processes, thus, polluting the people and the environment around. These problems are difficult to control without state control, because customers are not able to judge whether certain petrol is legal or illegal by simply looking at it.

In addition, petrol smuggling represent a life threat not only for smugglers but also for people around because of its explosive power. In the first semester of 1999, more than 40 people were killed in the region of Antioquia. Presumably, because of a technical failure that caused a huge blast of a pipeline carrying LPG. At first, the owner of the pipeline was blamed; however, there are strong beliefs that the blast was caused by a petrol smuggler who thought it was petrol-pipeline instead of LPG-pipeline. Thus, in their intent to perforate the pipeline it exploded creating a major tragedy leaving more than 40 casualties.

Amongst all the links in the petrol supply chain, refining is the most harmful environmentally. The refining processes affect all media, air, soil and water, and also produce solid waste. Nevertheless, air and water have the highest impact. The main contributor to the air comes from the furnaces where fuel is fired for heating the crude oil in connection with the distillation and cracking processes. The most important emissions are SO_2, NO_x, particulates and CO_2. The amount of each depends on the quality of the fuel and the cleaning facilities applied. A special problem here is that the refineries use quite a lot of the heavy fuel oil from the vacuum-fraction, and a considerable amount of the original sulphur and nitrogen is concentrated here.

The second major environmental issue for the refineries is wastewater discharge. All of it is discharged via the desalter, taking the salt out of the crude oil at its entrance into the refining process. This wastewater discharges causes an increase in Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD), which takes the river's oxygen. Other pollutants are suspended matter, nitrogen and phosphorus. It can fluctuate between 0.2 to 0.8 cubic metres of water per tone of oil refined (19). In the case of the Cartagena refinery wastewater is discharged into the Caribbean Sea, whereas in the case of the Barrancabermeja refinery, wastewater is discharged into the Magdalena River. Although there are water supplies downstream the Magdalena, the impact of the refinery's effluent is highly diluted, as the river flow is more than 1200 cubic metres per second at that point.

Pollution in refinery is inevitable; nevertheless, there are ways to minimize such pollution. But what is important to notice is that there is always a mass balance. In this way, pollutants like sulphur and nitrogen can either leave the refining process in products or in waste. Hence, low sulphur content in diesel or petrol means improved stripping and a further increase in the sulphur within the refinery waste. Trends are pushing towards taking out of the crude all the impurities and then disposing them properly without affecting all the consumers. As it was assessed in previous chapters, there is a trend towards producing cleaner products. It is achievable as long as the refiner undertakes the required investment in updating its equipment.

The Barrancabermeja refinery has undertaken some steps towards the cleaning of its products. About 40 per cent of the refinery's budget for environmental management is spent in controlling air pollution. The cracking unit recently built, for instance, has 0.1 per cent of its emissions of CO thanks to the latest technology available, that allow a complete combustion in its furnace. By contrast, in the cracking units of the fifties, about 18 per cent of emissions used to be CO (20).

In the case of the Cartagena refinery, the most important issue has been water pollution. It has had devastating consequences on flora and fauna in the sea surrounding the discharge point. Thus, the refinery has had to undertake heavy investment to treat its water effluents.

Lastly, regulations are always useful to exert pressure on refiner in order to keep improving the environment of one of the dirtiest industry of any country. In Colombia there is legislation for fuel quality that covers a great deal of refining pollution, hence, improving fuel quality mean updating machinery, and so, reducing pollution. In Colombia there is indirect legislation for the refining industry concerning other issues, like water and air, though, there is no specialized legislation for the refining industry.

3. INSTITUTIONAL AND POLITICAL ANALYSIS

3.1. Ecopetrol as a monopoly vertically integrated

Ecopetrol was created in 1948 as a result of a 48-hour strike of its trade union that ended the 'De Mares' concession of the American Oil Company Troco. Since then, the Colombian oil industry has been ruled by the state owned company vertically integrated. Though, there have been private competitors in exploration and exploitation as well as in petrol wholesaling and retailing.

From the administrative point of view, Ecopetrol depends on the Ministry of Energy and Mines. There are five members on the Board of Directors headed by the Minister of Energy and Mines, all of them named by the president of the republic. The president also names the chief executive officer (CEO) of Ecopetrol. In this way, Ecopetrol is totally dependent on the political power, in particular on the will of just one person, the president of the republic. However, there is another major power that has always influenced Ecopetrol fate, the trade union 'Union Sindical Obrera' USO.

The government has assigned Ecopetrol the task of guaranteeing the supply of all oil derivatives to meet the Colombian demand. Thus, it has to do exploration, exploitation, refining, distributing, as well as doing the research under the criteria of efficiency and social responsibility, as it is written in Ecopetrol's mission (8). Moreover, it was attributed to Ecopetrol supplying the products demanded by the private petrochemical industry.

These issues have meant that Ecopetrol has not been managed as efficient as a private company. It has been involved in doing too many tasks with the result of not being really competitive in any of them in the international arena. The political influence has been devastated for Ecopetrol long term planning. Usually politicians are in their position for a small period of time knowing that they will leave soon, therefore, they have withrawn as much resources as possible from it for funding unrelated projects. Similarly, many administrations appraised Ecopetrol's infrastructure projects using a much lower discount rate than if private companies would do them. Additionally, although recent

changes, sale prices of Ecopetrol's products have been heavily regulated on the basis of providing subsidies for the Colombian consumers in products of massive consumption. It means that there has not been an appropriate environment for having more companies participating in the oil market in Colombia.

Ecopetrol has been pushed by political influences to investments with no return on capital at all. For instance, in eighties, Ecopetrol was obligated to invest US$1billion on the huge coal mine of 'El Cerrejon' in the north of Colombia. The government participated in a shared association with Exxon to exploit the largest Latin American opencast mine. Unfortunately, after enormous expectations, it turned out to be a non-profitable business; thus, Ecopetrol did not see any return on its invested capital. Other example are the investments Ecopetrol has undertaken in refining equipment to improve petrol quality without increasing prices to the consumer reflecting production costs.

The link between management and temporal political interests resulted in more frustrations for Ecopetrol. For instance, the entire main gas-pipeline grid of the country was built under the Built Operate Maintain Transfer (BOMT) system by Ecopetrol, and once finished, the whole assets were transferred to the new Colombian Gas Company (Ecogas) in 1998 (28), leaving Ecopetrol with the financial obligations. Likewise, Ecopetrol has been involved in funding power plants when blackout occurred in 1992. What is more, these investments prevented Ecopetrol from saving economics resources to be able to afford pension liabilities in a medium and long term. It can now be partially blamed for the enormous burden that pension liabilities pose over the economic viability of Ecopetrol.

The fact that Ecopetrol has been both vertically and horizontally integrated, as the only petrol supplier, has resulted neither in an efficient nor in a profitable oil company, even though it has been told that being integrated may bring advantages. According to the Executive Director of Morgan Stanley, Nick Antill, there are two strong reasons for being vertically integrated. The first is that it may reduce transaction costs. If an operation is not integrated, then it will have to buy from and sell to a market. This requires finding out what a market clearing price is. There may be some costs associated with the transaction itself. Although these costs have decreased due to the creation of transparent prices and forwards market in oil products, it is still more expensive paying for the transactions costs than not paying for it at all.

The second reason is that it is worth being vertically integrated when the transport infrastructure is fixed and therefore it represents difficulties in the creation of a mature market. For instance, transporting liquefied natural gas (LNG) requires special tankers that can only be paid back if full utilization is guaranteed. Thus, company normally owns these tankers. In the Ecopetrol case, it owns the whole pipeline grid allowing free and unrestricted use to take its products to the consumer in towns as well as exchanging products between its refineries.

It is important to realise that being unbundled is not necessary the ideal situation, indeed, studies of 234 companies within the oil industry between 1974 and 1993, proved that profit-based measures of performance do not allow a ranking of companies according to the degree of vertical integration (30).

One interesting example is 'Petroleos de Venezuela (PDVSA)', the Venezuelan oil company, whose strategy of becoming vertically integrated resulted in not the benefits initially expected. There were four main arguments to go vertically integrated by investing abroad. The first was revenue maximization through participation in all the segments of the industry, and a full utilization of assets. This argument, although plausible from an individual company's perspective at a particular point in time, did not hold when viewed from a long-term market-wide perspective.

The second argument was to avoid the price-cutting wars that have generally accompanied cyclical contractions in the oil market, without having to cut their production volumes at the same time. However, it was not the case, an integrated producer, even if running its own oil through its own refining system, in the end has to face choices that confront non-integrated producers competing in a market. Thus, whether to cut volume or prices according to the supply/demand ratio. If neither are changed, it will find itself unable to sell the refined products, as they are too expensive, or it will achieve negative refining margins, because it sells the products at the same price as everybody else paying more for its feedstock.

The third justification for downstream integration was revenue stabilization. On a conceptual level, this seems to be well founded. After all, when oil prices fall, it can be expected that profit on the downstream will compensate an integrated market player's losses on the upstream, and vice versa. However, the truth is that the gains derived from being integrated downstream can only be of a short term character, because competition will inevitably bring about adjustments in refinery margins, taking these to levels in line with the long term price perspective of crude oil. Thus, a downstream network will only shield an exposed oil producer for a limited period, because high refining margins will act as signal for more refining capacity to come on stream, and this will eventually bring the margins down again.

The last argument PDVSA had for its integrating strategy was a technical one. Because PVDSA feared not having buyers for its heavy oil (under 15 API grades), it looked to build high conversion refineries to ensure that its oil will be in demand. Unfortunately, it resulted in heavy investments in a very difficult business due to stricter environmental regulations and over-capacity. Additionally, other companies like 'Petroleos Mexicanos' PEMEX, the Mexican oil company, having the same problem of very heavy and sour crudes, managed to hedge its crude production by using successfully the future options market. In this way, PEMEX did not need such heavy foreign investment to market its crude (31).

Because of the fact that Ecopetrol has not yet been involved in foreign investment, the PDVSA and PEMEX experience can be important lessons to learn. Likewise, although Ecopetrol should have been more competitive because there is not a mature market in Colombia and there is a fixed transporting infrastructure, it is not the case. In this way, Ecopetrol's problems may be attributed more to the way it has been managed and the way it has been manipulated by governments and the union.

In the past, it was frequently assumed that maintaining a reliable national energy supply depended on public ownership and state monopoly. But so far, this approach is now widely discarded. The strategic importance of oil is as ever, but most governments now perceive energy supply as a service best delivered by competitive markets. Competition is being introduced into every area of the energy field; and investors from all over the world are being encouraged to enter liberalized markets.

The reasons why this is happening lies on technological and economic efficiency. It has been widely demonstrated that focusing on economic performance, though may not involve directly a social purpose, brings better results in the long run. Hence, companies can provide oil-related services at a lower cost and in a sustainable and growing way. There are various reasons for that, for instance, the seriousness and accountability from owner to their company. A private company is carefully managed because only a few people will be badly affected by the consequences of mismanagement, whereas, if a state-owned company owned by 'every citizen' made losses, nobody is directly harmed. Consequently difficulties in company performance would have a stronger affect on private owned than on state owned companies.

In the case of Ecopetrol being unable to undertake long sustained planning political volatility is to be blamed. It is absolutely nonsense having six different CEOs in less than 5 years. It simply makes long-term planning impossible, knowing that this is required due to the very nature of the business. Furthermore, the very ambiguous vision of covering 'everything' may lead to low quality in the end, as efforts made are diluted.

Additionally, Ecopetrol has been highly susceptible to excessive concessions to the trade union, because of its political dependence. Politicians quite often manage the company under populist ideas that actually threaten its efficient performance. For instance, providing excessive subsidies to get votes on polls, giving excessive concession to the trade union in order to gain votes and avoid unpopularity. These ideas are among the reasons why Ecopetrol fate must not be other than a structural change in vision and management.

3.2. Free market in petrol supply to Colombia

Nowadays there are three main trends that describe what is happening in the oil industry. First, a move away from state-owned oil companies towards privatization and deregulation in the oil business eliminating subsidies and liberalizing prices. Second, increasing transparency within the business, hence, every body is working under the same rules no matter religion, language, country, etc. For instance, South Korean firms are now bidding against Exxon for blocks in Libya, Malaysia's national oil company, Petronas, is buying South African Engen, and Argentina's former national oil company

YPF has purchased the American independent Maxus and is in turn being acquired by Spain's recently privatized Repsol. Third trend, a shift in corporate strategy from the strategic model to the profit-oriented model.

These trends are shaping a new scope for the oil business; it is now neither a local nor even a regional business but a global one. Likewise, as competition get harsher and harsher, companies are becoming bigger and bigger to take advantage of economy of scale and to achieve more stability as well as gaining new potential markets. In this way, the world has seen mergers such as BP-Amoco, Exxon-Mobil, Lasmo-Monument, Repsol-YPF, which aim mainly to reduce their production cost per unit of output in order to became more competitive. It means being able to sell high quality products at prices lower than its competitor.

Implicitly, it has been more important to run a business with a long term outlook rather than the usually short sight of state companies politically influenced. For instance, in the 1980s, during the Japanese economic boom, much of their success was attributed to a superior strategic focus, which was said to be much longer-term than American companies. They would sacrifice short-term profits in order to increase or maintain market share or gain entry into a market that would later provide excellent returns. American companies would pass up any opportunities that did not provide immediate gratification, partly because of pressure from Wall Street.

Many expected Japanese companies to dominate their industries in coming years as foreign competitors refused to invest at the low rates of return accepted by Japanese, and companies with short-term strategies ultimately saw their volumes wither away. In the oil industry it was not really noticed because the Japanese industry did allow refinery capacity utilization to sink to 61% in 1982, and refused to reduce their service station population. On the other hand, the US industry cut 3 million barrels a day of capacity, thereby increasing its utilization to 93%, and closed about half of its service stations (32). Even though, there is no major difference in the results of oil companies nowadays, illustrates the importance of long term planning.

3.3. Strategic alliances and joint ventures

It is clear that perhaps the quickest way of solving the main Ecopetrol's problems at the moment may be by privatizing it. However, it is not the right moment for undertaking such a measure. On the one hand both Colombia and Ecopetrol are not ready to attract a good bid. On the other hand, it would be extremely costly due to the huge popular opposition to privatization. However, there are other ways to heal Ecopetrol's pains. For instance naming its staff by merit and its CEO for longer and fixed periods to provide more administrative stability and breaking the super power that lies only on the president of the republic hands. Likewise, globalization of Ecopetrol should be accelerated in order to boost transfer of technology and inflow of capital. It would be the fuel of Ecopetrol modernization going for a more profit-guided emphasis in which it could take advantage of its geographic position. It can be done by encouraging joint ventures and strategic alliances.

Just as a matter of example, in the years 1996 and 1997 more than 20,000 alliances were formed worldwide, and approximately 75 per cent of those have been across borders. Nearly 15 per cent of the revenue generated by the top 1000 US firms comes from alliances; this is a fourfold increase since 1987. The average return on investment from strategic alliances is more than 16 per cent, significantly higher than the average return from the same corporations (33). Within the oil industry, alliances have been undertaken about a 50 per cent in upstream, 40 per cent in downstream and the rest in services.

There are, even, three circumstances in which strategic alliances can be more advantageous than privatization. The first circumstance is characterized by the saying 'distance does not make the heart grow fonder'; privatization might be difficult to integrate when spanning long distance and crossing borders. The second is 'the empty-nest syndrome'; too often the best people may leave when a company changes its owner. The third is 'same bed, different dreams'; trust-building and strategy formation are harder in acquisitions because of the cultural differences which have to be overcome (34).

3.4. International outlook

It is important to study at what other countries are doing to tackle inefficiency of state-owned oil companies in order to see if there is anything useful and applicable to the Ecopetrol case.

3.4.1. Venezuela

PDVSA operates the Western Hemisphere's largest refining system, and is the world's fourth largest oil refiner, with a combined domestic and international capacity of about 3 million barrel a day (MBD). Domestic refinery capacity stands at about 1.2 MBD, from which in the Paraguana Gulf there are 940 TBD, one of the largest in the world. In the same way, PDVSA's US refining and marketing subsidiary, Citgo, is the largest US petrol retailer with 14,855 service stations throughout the country.

Venezuelan petrol for own consumption is heavily subsidized, thus, its price is well below the international level and as a result there has been a booming of petrol smuggling to Colombia. Especially, since it phased out subsidies in January 1999. In mid-1999, Venezuelan Energy Ministry presented plans to liberalize domestic petrol and diesel markets by gradually lifting state subsidies on these products. However, this and similar proposals in the past has been halted due to political opposition, as petrol prices are a politically sensitive issue, and therefore Venezuelan petrol prices remain among the cheapest in the world. Even the head of the country's refining industry does not support freeing petrol prices fearing losing market share due to competition (36). Thus, in petrol pricing Venezuela lags behind Colombia in deregulating the business.

However, unlike Colombia, Venezuela has managed to get private capital into the downstream sector. It happened after the Venezuelan government authorized a private company to take an equity stake in the 195 TBD Puerto La Cruz refinery, on the East Coast. This is a major producer of unleaded petrol. Moreover, PDVSA's petrochemical plans are to double its output, which in 1998 was 7.2 million tons, making most of it for exports. Such figures overwhelm any Colombian need, and posses a severe competition against Ecopetrol. This constitutes a real challenge for the expansion plans of the Cartagena refinery towards petrochemicals production (35).

Additionally, Venezuela has approved four joint ventures in extra heavy crudes over the past few years in which PDVSA is a minority owner with several other companies including Conoco, Mobil, Statoil and Texaco.

Amazingly, despite the fact that Venezuela shares more than 2000 km of frontier with Colombia, and that they are both the second foreign trade partners, Ecopetrol has not a single business with his oil giant neighbour. Apart from possible diplomatic difficulties between the two countries, it shows how inward looking Ecopetrol's scope of the business, has been.

The fact that Colombia has such an oil giant neighbour with tremendous influence on Colombian's internal energy issues posses a challenge for Ecopetrol managers to tighten commercial and diplomatic links with Venezuela. Oil in both countries represents the most important source of fiscal revenues, what Venezuela is doing and plans to do must be taken into account by Colombian oil policy-makers.

Plans for privatizing PDVSA have not even been considered. But, today's situation proves how harmful the political influence can be over a state-owned oil Company. For instance journalist Patrick Crow reported in a prestigious American magazine: "Since taking office last February (1999) Chavez (the new Venezuelan president) has named three persons with limited oil industry experience to the PDVSA board… Eyebrows also were raised when the government named an army officer with limited experience to be PDVSA's chief financial officer and a former oil industry employee with no senior management experience to a critical planning position… The Chavez team also made a political decision to keep tight controls on retail gasoline prices, forcing international oil companies to scale down planned multimillion-dollar investments in Venezuelan marketing…(37)"

3.4.2. Brazil

Amongst Latin American state-owned oil companies, Brazilian PETROBRAS is making the pace of transformation involving private capital and focusing on profits and improving efficiency. Brazil contains the second largest oil reserves in South America, after Venezuela, although it continues to strive for self-sufficiency in oil production.

Since its creation in 1953, PETROBRAS has had a monopoly over the rights to exploration, production, refining, distribution and the international sale and purchase of oil throughout Brazil. However, PETROBRAS sole position came to an end in July 1998 when the government announced that more than 92 per cent of the nation's sedimentary basins were to be put up for bidding by other oil companies. In fact in June 1999, 12 blocks were sold to 10 foreign firms. Moreover, the new board is preparing PETROBRAS for a future international stock exchange listing, where the government will intend to sell 31.7 per cent of its share (38). The sale of this stock will leave the government with the minimal share required to maintain voting control, just over 50 per cent. In the same way, PETROBRAS is expected to sign a dozen oil development partnerships with private firms in order to be able to get the US38 billion needed for the development plan until 2002.

PETROBRAS inefficiency reflected in costs 25 per cent above the benchmark has been tackled by introducing modern management structures on to the company by dividing it into business units, creating profit centres and introducing benchmarking for all activities. The new manager is hiring international consultants to advise on strategic planning, a new business plan and internal reforms. Mr Philippe Reichstul, CEO, says that PETROBRAS is vertically integrated to such an extent that "you do not know, for instance, how much exploration makes" (39).

As usual, the main constraint in Latin American oil companies is the dependency on politicians. As it is crystal clear in a journalist's description: "The restructuring of PETROBRAS is moving ahead. The only cloud on the horizon is political" (40). The main reasons for that have already been explained, but there is another reason. People do not understand the importance of investing in exploration because it is not tangible, so they tend to exert pressure onto politicians to encourage refining instead of exploration projects.

Although the PETROBRAS restructuring process is still in the early stages, it is worth looking at, to learn lessons for ECOPETROL. As it can be observed, there are a lot of things in common amongst Latin American oil companies, and comparing experiences can contribute to finding solutions to their problems.

3.4.3. Mexico

The Mexican oil company, 'Petroleos Mejicanos, PEMEX', is the world's sixth largest oil company, the single most important entity in the Mexican economy, and a symbol of Mexican sovereignty and independence. It is vertically integrated controlling the whole oil sector in Mexico from exploration to distribution. Its monopolistic functions are written in the Article 27 of the national constitution, thus, placing difficulties on foreign investor. However, because of volatility in oil prices PEMEX has not been able to hedge its oil revenues, as a result it has been forced to look for private capital in order to be able to finance its development projects. In this way, PEMEX has announced recently that it will seek US$5.8 billion in private investments to modernize refineries and boost production.

Furthermore, because of heavy competition from the US Gulf Coast, the Mexican government also plans to continue to sell minority stakes in PEMEX's petrochemical plants to private investors. In fact, petrochemicals accounts for more than US$3 billion per year in trade deficits with the US, as Mexican plants cannot obtain quality at a competitive price of petrochemical products, and must import them from the US. Nevertheless, even minimum privatization is politically sensitive and highly unpopular due to fear of lost jobs. Therefore, despite the current great need of heavy investment in upgrades, obtaining private capital is the most important challenge of the Mexican oil sector.

One of the ways PEMEX is using to tackle these problems is by having joint ventures with foreign companies abroad. For instance, PEMEX has contracts with US refiners to process Mexican crudes. An important source of petrol (up to 45 TBD) for Mexico is the 255 TBD Deer Park (Texas) refinery. This is a US$1 billion a year joint venture between PEMEX and US Shell Oil Co. PEMEX supplies around 135 TBD of its heavy Mayan crude to the refinery and in turn imports petrol produced at the refinery (41).

What is more, PEMEX has been working jointly with the US to understand and model the complex phenomena involved in the emission of pollutants, in their dispersion, and in the atmospheric photochemical reactions that finally contribute to the high levels of pollution registered in Mexico City. Sophisticated modeling techniques, coupled to economic analyses, are being used to conduct feasibility evaluation of different

alternative options to address specific environmental problems, so that the most cost effective solutions can be identified (43). In this example, it can be seen that globalizing the business brings enormous advantages, far beyond straight profitability, transfer of technology and know how. The seeds to achieve competitiveness in the future.

PEMEX is also looking to make other strategic alliances and joint ventures to increase its ability to process high sulfur crude, which makes up most of Mexico's oil production, and mitigate the problematic bringing of foreign capital to the country. In fact, there are some politicians that have already proposed that PEMEX should issue shares on the stock market and open itself to private and foreign investment (42). It is a landmark toward deregulation in the future.

3.4.4. Argentina

Argentina's energy industry has been revitalized in the 1990s as a result of its drastic restructuring, in particular, the privatization of former state company 'Yacimientos Petroliferos Argentinos – YPF' in 1993, and a dramatic increase of private and foreign investment. In June 1999 Spain's oil, natural gas and chemicals group, Repsol, completed its US$13.5 billion takeover of YPF, creating the world's tenth largest oil and gas company (by market capitalization).

Three companies control the downstream oil sector in Argentina: Repsol-YPF, Esso and Shell. These companies are investing in upgrading capacity to produce lighter products as the country completes the switch to unleaded petrol and complies with more stringent environmental regulations.

In Argentina private companies are permitted to import, export and sell oil and oil-products without major restrictions, and can participate in all segments of the industry. Likewise, prices of crude and oil derivatives, as well as distribution facilities have been liberalized. The petrochemical industry is mostly privatized. YPF has also been involved with PETROBRAS of Brazil in the process of planning to jointly operate 1500 service stations in the two countries and planning other fuel distribution joint ventures as well.

Although the restructuring of Argentina's oil sector has had social costs as YPF made redundant 80 per cent of its employment force in three years since its privatization in 1993, it is expected to cause retail prices to drop between 6 and 10 per cent (44).

3.4.5. China

China's refining industry, the second largest in the Asia-Pacific region, was until recently, heavily regulated by central government and monopolized by the state-owned SINOPEC. However, significant changes have taken place since last year's restructuring. It consisted of the break up of the long-standing sector monopoly of China's oil and gas industry into two companies creating a state-controlled duopoly model. Before the transformation SINOPEC held 95 per cent of the refining sector, and CNPC produced 90 per cent of China's crude oil. After restructuring the sector, both upstream and downstream activities were assigned for SINOPEC in eastern and southern and to CNPC to the northern and western China.

It created competition between the two companies in the oil product markets. Although the reform scheme restricts the two companies to operating production facilities under geographic division, it does not limit them from distributing products across each region. Soon after the reorganization, CNPC launched a marketing battle in south and east China, now the territory of SINOPEC. Then, the government intervened to force CNPC to sell its surplus oil products in south and east China through SINOPEC, rather than marketing them directly.

In theory, direct foreign investment in China is allowed in the refining sector, but in practice there are only four foreign players that have, some extent, gained access to refining businesses. These includes a TOTAL's equity joint venture, an ARCO's acquisition of a stake in a petrochemical plant through the Hong Kong Stock Exchange, and ARAMCO and EXXON's involvement in a refinery. None has officially been granted permission to operate in the retail market, even though a number of foreign companies are doing some business of this kind with the approval of local authorities.

However, opportunities for foreign companies to be involved in adding new refining capacity and operating in the market are set to increase over the next decade for three

main reasons. Firstly, intensified domestic competition will force Chinese companies to look for foreign alliances, as it has already happened in other industrial sectors in other Asian countries. Secondly, the Chinese government and refiners are facing increasing difficulties in financing new refining facilities through borrowing and issues in domestic and foreign capital markets and are being forced to look to foreign sources through equity joint ventures. And thirdly, China will have to liberalize its heavy regulated retail sector, including petrol products, in order to gain full membership of the World Trade Organization (49).

3.4.6. Indonesia

PERTAMINA was created in 1969 as a state-owned monopoly charged with managing Indonesia's oil and gas development. Over the years, it has operated almost as a sovereignty onto itself, ignoring transparent business practices, often acting independently of any ministry, and increasingly taking on the role of a cash cow for the government's financial needs. With time, there was the realization that something had to be done about PERTAMINA's inefficiency. In 1993, the company began a restructuring programme that reduced production costs to US$5.1 per barrel from US$11.7 per barrel, and reduced the company's work force to 30,000 from 45,540.

The reformers believe that competition would gradually lower prices for refined products, helping to offset the effect of government moves to slowly peel away subsidies that provide Indonesians with some of the world's cheapest petrol, diesel and kerosene. Moreover, it will clean corruption from the oil company and save a lot of money for the state. For instance, during the 32-year tenure of president Suharto, PERTAMINA awarded 159 contracts to companies linked to his family and cronies. These contracts were awarded without formal bidding or negotiation processes. In the same way, an independent audit report said inflated contracts cost PERTAMINA US$3.6 billion, and the oil firm lost US$1.2 billion because it failed to hedge its foreign exchange exposure. The audit said also that four of PERTAMINA's seven refineries would lose money in 1999, partly because the company lacks a system to determine the profitability of its petroleum products and partly because of emergency shutdowns and high need of maintenance, thus, deficient management (50). Another problem of PERTAMINA is that the regulatory officials of the company have been hopelessly underpaid, thus, they have had to resort to payoffs to survive.

3.4.7. Other Countries

It is interesting to see that restructuring of state owned companies throughout Latin America has been undertaken under very similar grounds to tackle pretty much the same problems such as lack of economic and technological efficiency and excess political influence in management and planning.

In Ecuador the government has plans to grant the state-owned oil company, PETROECUADOR, more fiscal and administrative independence. Additionally, it has plans to tender the 46 TBD 'La Libertad' refinery via a 20-year concession to a private investor by the end of 1999. It aims to find a private company to finance the US$150 – US$200 million needed for the modernization and expansion of the refinery capacity to 60 TBD. It will incorporate a new catalytic cracker, a coker, and possibly building a thermal power plant that would burn the coke and produce cheaper power for the facility. Amongst the main problems the government faces are political interests and strong labour union.

Chile's energy sector is largely in private hands. The opening of the petroleum sector, reflected in the free access to imported fuels, has allowed most economic sectors to expand and improve services at competitive prices. The oil upstream business is managed by the state oil company, 'Empresa Nacional de Petroleo – ENAP', whilst the refining are carried out primarily by three state-owned refineries. Additionally, the private sector is in charge of the country's oil distribution system. Prices are established according to an international parity scheme that compares international to local prices. ENAP is also involved in joint ventures in the petrochemical industry (46).

In Bolivia, the government is taking measures towards privatization. It plans to partially privatize two of the country's three oil refineries owned by the state oil company 'Yacimientos Petroliferos Fiscales Bolivianos – YPFB', the Cochabamba and Santa ruz refineries. By doing so, the government hopes to raise US$230 million from the sale. In addition, it will sell YPFB's liquid storage terminal facilities and service stations throughout the country. After that, YPFB will serve as an administrator of the natural gas export contracts with Argentina and Brazil, be responsible for international negotiations, and will administer the contracts signed with oil companies operating in Bolivia (47).

In Peru the state oil company, PETROPERU, was committed to privatization by the government in 1998. In 1996 Spain's Repsol bought 60 per cent stake of the Peruvian largest refinery, 'La Pampilla', however the planned privatization of Talara in 1995 was halted amidst protest from workers. This privatization plan called for selling 35 per cent of the Talara refinery with a 20-25 year concession. Thus, this reflects the great unpopularity of privatization in Peru. Workers did not even allow a minority stake of the refinery to be sold. In the end PETROPERU's privatization had to be pushed back indefinitely for social and national security reasons (48).

Libya has had a very interesting strategy for funding its refining capacity. In order to encourage private companies to develop the downstream side of the business, the government inserted a requirement in several concession contracts that the signatories construct refineries in Libya in exchange for exploration and production acreage. Unfortunately just in one case, however, as the result of an agreement with ESSO, the government did succeed in achieving this (51).

3.5. Institutional and legal framework required for a free market in Colombia

Interestingly, the problems of state-owned oil companies worldwide have been pretty similar. Probably the most important is the excess of political intervention, which prevent companies from having a stable administration and a consistent long term planning. In the same way, political intervention has forced state-owned oil companies to fulfil social objectives by providing subsidies in its products. That has undermined competitiveness sending wrong signs to both producers and consumers. In addition, state-owned oil companies have been overwhelmed by the capital investment needed for upgrading and expanding.

As a result of that, state-owned companies have been forced to join efforts with private sector as the best way of finding a solution for their economic and management problems. Thus, every state-owned oil company reviewed is undertaking strategies to deregulation towards creating free markets conditions involving private competitors. Ecopetrol, the Colombian state-owned oil company, is amongst the ones that have made

the least progress in such a matter. Nonetheless, undertaking such path is the only way to guarantee survival in the long run.

To achieve that a stable legal framework is required. Unfortunately in Colombia this has not been the case, recent studies showed that laws in Colombia is short lived, thus, laws are substituted very often generating a lack of trust on the legal framework. For instance, foreign private companies fear of changes in taxing policy, because it might affect their revenue stream.

Other factors required to make the oil industry attractive are having a stable and democratic political system, giving competitive fiscal incentives and quick decision-making by the government. Although in Colombia there have been important efforts to speed up the decision-making, it is still lags behind a competitive country. For instance, long time is taken by the Ministry of Environment before issuing an environmental license for energy related projects.

The viability of Ecopetrol lies on one hand, in the capacity of the government to undertake structural changes to push Ecopetrol into a more efficient company. On the other hand, on the acceptance of the labour union for making some sacrifices, particularly, when making changes to tackle overstaffing.

The first structural reform needed by Ecopetrol is achieving stability on its board. Hence, giving more autonomy and reducing political influence. Then, it is crucially important to set benchmarking targets in order to become more efficient and competitive. Furthermore, Ecopetrol should look for recognition of its quality obtaining the acknowledgement of fulfilment of the ISO 9000 and the ISO 14000 international quality standards.

Furthermore, Ecopetrol's scope should widen looking for transboundary exchanges bringing economic and technical resources. As it could be observed from varies state-owned oil companies, capital can be obtained by making strategic alliances and joint ventures with private corporations for specific projects. Moreover, issuing shares in the stock market can allow Ecopetrol to sell a minority stake to raise money for its plans. This can be done without the necessity of further wealth concentration if shares are to be bought by employees, national pension funds and general public.

The Ecopetrol vision of the oil business should be re-focused towards profits. It has been proven that by undertaking such focus a company performs better, thus, provides more benefit to the general public than an inefficient profit loss making company. Almost all of the major oil companies have the vision of creating value for their shareholders, though it may be viewed as an antidemocratic move. However, what must be understood are the final result of the strategies rather than being stuck to the means.

There is no doubt that the biggest challenge for a policy-maker in Colombia, who understands the nature of the changes Ecopetrol requires, is making people understand that the restructuring of Ecopetrol is the best alternative for the government and the nation itself. How to make people think for the long-term?

For example, scope of common multinational companies and their strategies in the oil business can be seen as a follow:

Exxon Corporation

- Develop best-in-class cost structure
- Increase sales of high-value fuels and specialty products
- Capitalize on refining integration with chemicals and specialties businesses
- Invest selectively in high-return refining projects
- Maximize total retail site earnings
- Rapidly develop and deploy leading edge technologies

Source: Exxon, 1998 Annual Report

One of Exxon's strengths is diversity of its businesses: exploration and production, refining and marketing, and petrochemicals.

Chevron Corporation - Refining

- Committed to meet the needs of the core customer-driven businesses – quality gasoline, lubricants, aviation fuel and diesel. These products will be provided on-test the first time, delivered on time and for the agreed-upon volume.

- Ensure safe, reliable and incident-free operations by using safe operating practices, training employees, improving equipment reliability and complying with all environmental and safety standards.

- Achieve lowest sustainable operational cost by operating refineries efficiently and reducing operating expenses and cost of goods sold, without compromising safety or environmental standards.

- Strive to maximize economic utilization of assets and optimize feed selection and yields.

- Leverage efforts throughout refinery system to take advantage of economies of scale. Identify and incorporate “best practices” in all operations.

- Improve the quality of products and services continuously and provide them reliably and predictably.

Chevron Corporation Supplement to the 1998 Annual Report

4. ECONOMIC ASSESSMENT OF ALTERNATIVE SCHEMES

4.1. Previous applications of Linear Programming in the oil industry

Application of mathematical programming in oil industry began in the fifties to find the optimum recipe in petrol blending. It is important to notice that commercial petrol has always been a product made of blending many elements. Each of them has its own properties and cost, so the LP models address the recipe that would enable the refiner to meet quality requirements at the least cost. Also today, LP models are heavily used to develop reformulated recipes to meet very tough environmental constraints. For example controlling toxic emissions like nitrogen oxides, and volatile organic compound (22).

Soon, it was discovered that LP represented idealistic situations far from the real world. The LP over-optimized in the sense that the predicted performance was better than could be achieved in real operation. It means that, on the one hand it should be taken into account error margins to interpret the results, on the other hand, it was needed to add more constraints to the LP models in order to get a better approximation. However, it could only be possible with time, as computing facilities developed and LP become more common. In the early seventies, many of the major oil companies embarked upon in-house development projects for LP model management systems, such as Amoco's MARS, Shell's AMBUSH, and Exxon's PLATOFORM.

Later, LP models started to be used in other optimization problems within a refinery. For instance, finding a method to get the best process flow and heat exchanger areas for a crude unit heat exchange train in distillation. Crude oil distillation produces six or eight products at temperatures ranging from few to several hundred Celsius. The heat contained is recovered by preheating the crude oil in several heat exchangers before it is sent through a furnace and into the distillation column. The problem is, then, which streams to exchange heat between, and the number and size of heat exchangers required to achieve maximum economic heat recovery saving fuel of the furnace (21).

In addition, LP models are being used to optimize the feedstock when it is possible. Hence, there are various feedstock alternatives, classified by their gravity (API) and sulphur content, from which to select as well as there are different marketable conditions.

Each type of feedstock (crude) yields a distinct array of products for each mode of refinery operations, moreover, each crude cost differently (23).

Although there are a few pipelines to transport crude to the refineries in Colombia, there are more than 180 different in their 'assay' (properties). In this way, LP modeling is needed to decide what crudes should be within the 500 TBD exported and what should be part of the 300 TBD refineries throughput. Ecopetrol uses the Process Industrial Modeling System (PIMS) that is currently widely used within the refining industry worldwide. This is an LP model that contains information about crudes, pipelines, and each of the process of the Barrancabermeja and the Cartagena refineries. PIMS is run monthly in order to adjust the planning of the refineries' deliveries according to changes in the market and/or in technical availability.

Interestingly, one result is that it is better for the economy of Ecopetrol to import heavy Venezuelan crude for the Cartagena refinery even being Colombia net oil exporter. The reason is because, the Cartagena refinery was designed for a heavy-crude feedstock, then common in the market, and there have been discoveries of lighter crudes in Colombia since. Therefore, it is better to sell light crudes abroad at a higher price and import cheap Venezuelan crude than investing in the Cartagena refinery to adequate it for lighter crudes as feedstock. Furthermore, the PIMS is an important tool to decide how much petrol to import based on the refineries output.

PIMS is a very specific programme rather limited to short term planning. Making changes in its input data is pretty complicated due to the large amount of basic information that has to be given. Therefore, it is not a flexible and easy LP tool that can be use for assessing different schemes in the long term under different scenarios of petrol demand.

The LP model used in this dissertation, though much simpler than PIMS consider a longer period of time and it is focused on economics, but of course, it has by far less accuracy.

4.2. Aims

- To calculate the optimum combination of petrol supply, hence, the share of petrol refined locally and the share of petrol imported that make the least cost. It is the scheme 3

- To do sensitivity analysis under different scenarios of petrol demand, international price of petrol, payback periods (expected profitability) of investments in expansion of both pipeline and refinery capacities.

- To appraise three different schemes of petrol supply to Colombia.

4.3. Questions to be answered from the LP Model

- Regarding the three scenarios of petrol demand what would be the optimum price differential between the international petrol price and the cost of refined petrol that makes no justification for imports?

- What is the least capital-intensive way of petrol supply for the three scenarios of demand in 2010, and under what price differential?

- What is the most capital-intensive way of petrol supply for the three scenarios of demand in 2010, and under what price differential?

- How sensitive is the petrol imported share in 2010 to changes in the payback period (expected profitability) of investments in expansions of both refinery and pipeline capacities?

4.4. Input Variables

- Demand of petrol in the Barrancabermeja refinery in the year 2010

In the Barrancabermeja refinery site petrol demand accounts for 83% of the national demand. Petrol reaches the storage tanks of the Barrancabermeja refinery no matter whether petrol comes from importation or it is refined. These storage tanks are one stop of the importing pipeline Pozos Colorados – Galan that connect the centre and west of the country (Appendix 5 and 6). The three different scenarios of demand can be seen in Table 3.

PETROL DEMAND AT THE BARRANCABERMEJA REFINERY IN 2010

(Thousand Barrels per Day – TBD)

Scenarios of Petrol Demand	High	Ecopetrol	Low
Gross Demand	181	153	135
Net Growth of Demand	87	53	31

Source: Appendix 4

TABLE 3

- Refining costs of the Barrancabermeja refinery and international petrol price.

Every single variable involved in the production costs changes in a monthly basis and it seldom remains the same from one month to another. It can be seen in Table 4 that the production cost of a refined barrel has fluctuated

ECOPETROL STRUCTURE OF REFINING MARGIN

(US$1999/barrel)

	Barranca. April, 1999	Ecopetrol April, 1999	Ecopetrol March, 1999	Ecopetrol 1998
Income from sales	19.40	18.60	16.53	17.29
Crude costs	13.11	13.53	11.31	11.08
Gross margin	6.29	5.06	5.22	6.21
Operational costs	3.28	2.99	3.10	3.98
Operational margins	3.01	2.07	2.13	2.23
Financial and labour liabilities	3.05	2.71	2.82	3.6
Net margin	(0.04)	(0.65)	(0.69)	(1.05)

Source: Monthly Report April 1999, Direction of Corporate Planning - Ecopetrol

TABLE 4

from 14.41 to US$16.52 just in 30 days. The reason is the volatility in oil prices; indeed, oil prices increased nearly 100 per cent in a period of only sixth months of 1999.

However, it is not the main concern in the structure of the refining margin, the crucial variables are operational costs and financial and labour liabilities (non-operational costs). These two variables depend on efficiency of a refinery in terms of management, technology used and economy of scale. Their magnitude is inversely related to the profitability of the business, in Ecopetrol's refineries it has been negative as can be seen in the last line of Table 4 (net margin).

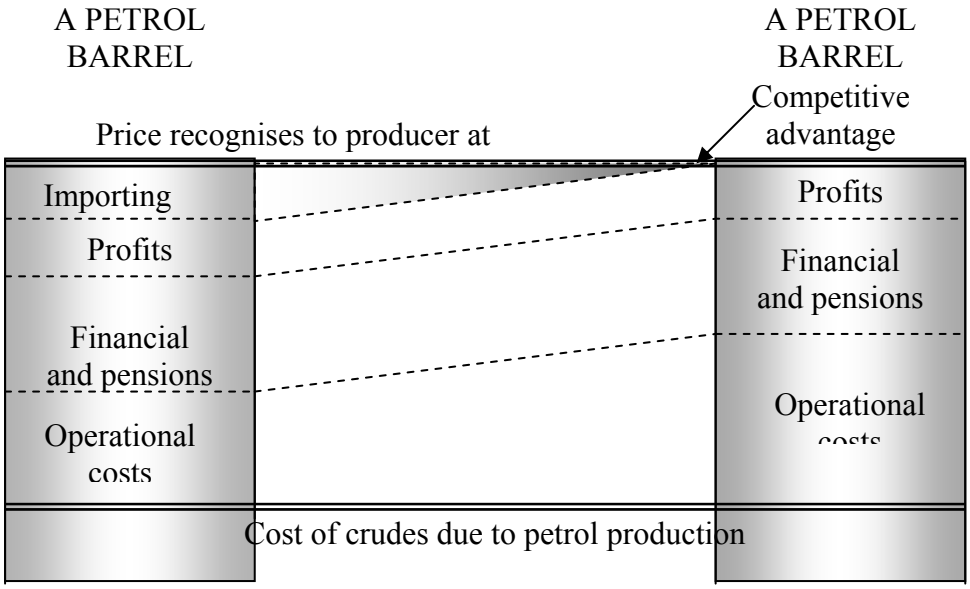
Contrary, both crude and product prices that determine the gross margin depend on the interaction of free market in the international arena. In real world this is not totally true in the Ecopetrol case due to the fact that pricing in some of its products are still regulated by the government.

All in all, the economic analysis that will take place in this dissertation is about margins. Hence, assessing the difference of gross margins between Ecopetrol and its foreign competitors. It is assumed that the crude prices are equal and there is perfect competition. In Diagram 6 are depicted the margins for a barrel imported and for another refined at the Barrancabermeja refinery. It is important to notice that these margins are at Galan station, which is at the Barrancabermeja refinery (Appendix 5) in order to be able to compare the two alternatives.

Looking at the Diagram 6 it can be observed that there is a very important competitive advantage to the Barrancabermeja refinery. It is the importing cost that should be undertaken when importation of petrol. This figure can be around US$3.45 per barrel of petrol as it is depicted in Diagram 6. Though, it may seem too high, gross margins attributed to petrol production are quite high. For instance, in the Barrancabermeja refinery it was around US$13.30 per barrel in 1998 (10), using average exchange rate of 1998 (1283$Colombian per US dollar).

From Diagram 6, it can be seen, that refining at the Barrancabermeja refinery is better than importing only if its operational costs, plus its financial and labour liabilities are less than the sum of the same variables for the imported petrol, plus the importing costs. This assuming the same net margin, hence, the same profitability.

PETROL MARGIN: REFINED *vs.* IMPORTED



* This item is composed by:

Freight fare ≈ 0.80 US$ per barrel

Transport insurance ≈ 0.25 US$ per barrel

Importing tariff ≈ 1.50 US$ per barrel

The 'Timbre' tax ≈ 0.10 US$ per barrel

Importing pipeline fare Pozos Colorados – Galan ≈ 0.80 US$ per barrel

Total importing costs ≈ 3.45 US$ per barrel

NOTE: These prices were deduced from a US$20.5 per barrel production cost of regular petrol in the US Gulf Coast taken from EIA (24)

DIAGRAM 6

- Payback period expected for investments in expansions of refinery and importing pipeline capacity.

For marginal investments in expanding the Barrancabermeja capacity it is expected a payback period of 6 years, which is an approximation of a 10-12 per cent rate of return (above current figures Table 4A). In the case of investments in

expansions of the importing pipeline it was assumed an expected payback period of 3 years, which is an approximation of a 20 per cent rate of return. Thus, it is assumed that expansions of the importing pipeline should by more profitable in relation to expansions of the Barrancabermeja refinery. This is trying to internalize social costs associated to expanding the pipeline and not the refinery.

RETURN OF CAPITAL IN THE BARRANCABERMEJA REFINERY PERFORMANCE

	1992	1994	1996	1998	March/99	April/99
Utilization, %	83.8	80.1	75.0	75.9	86.9	82.7
Operational margin, US$/barrel	1.8	1.8	2.8	2.7	2.9	3.0
Return of capital, %	6.5	6.5	9.7	9.3	9.0	9.5

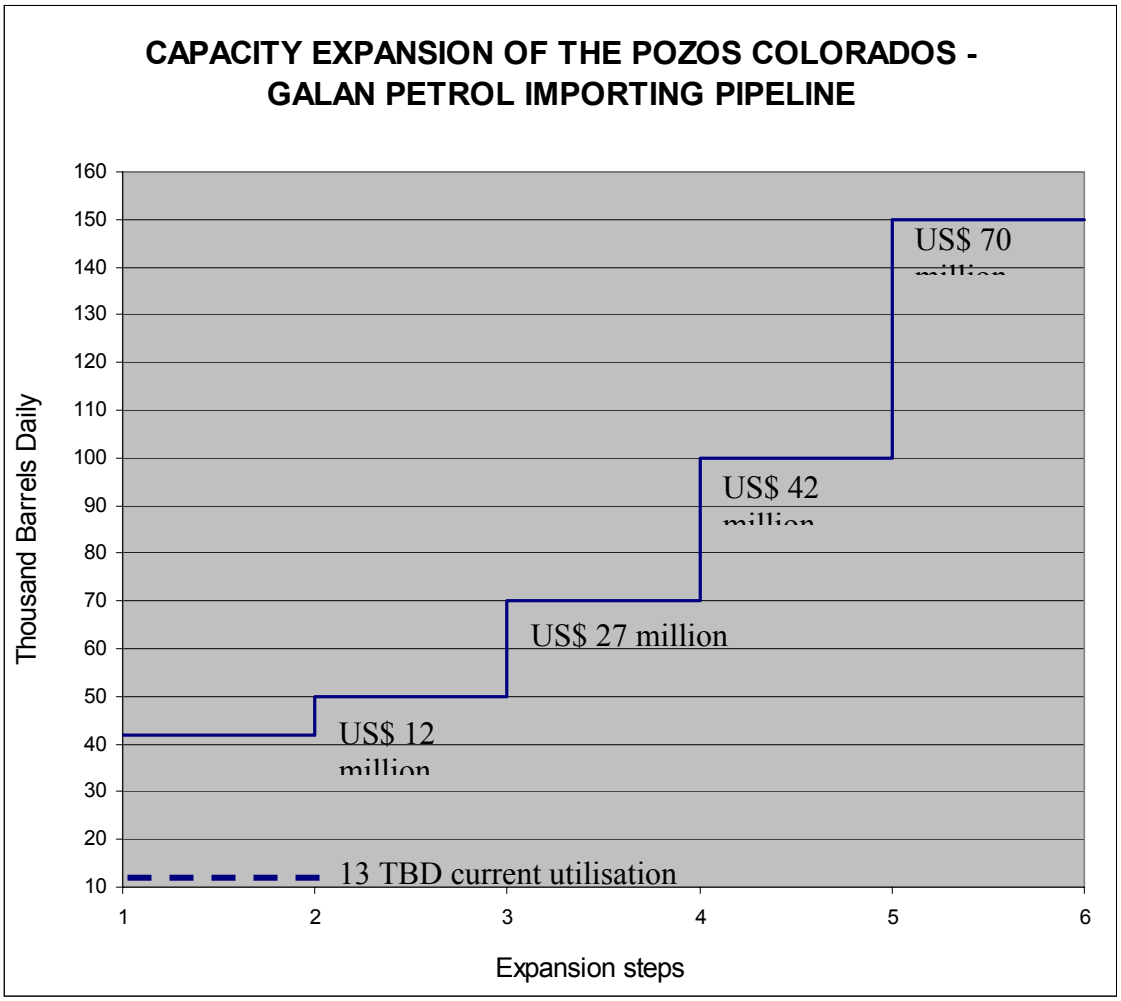
Source: Monthly Report April 1999, Direction of Corporate Planning - Ecopetrol

TABLE 4A

- Functions for expansion of both the Barrancabermeja and the Pozos Colorados – Galan importing pipeline capacities

Graph 4 shows the relationship between marginal capacity increases and marginal investments in the expansion of the Pozos Colorados – Galan petrol importing pipeline. Capacities indicated in the Graph refer to available capacities, not nominal capacities. For instance, today's nominal capacity accounts for 51 TBD (25); nevertheless, real maximum capacity is 42 TBD due to technical flaws throughout the pipeline. In the horizontal axis it is depicted the steps of the optimal expansion of the pipeline from the technical and economic viewpoint.

1-2: It is the present state of the art, therefore, marginal investment equals zero.
2-3: The first expansion takes place by building a new 200 thousand barrels at Galan station. The current lack of storage capacity unable the Pozos Colorados – Galan pipeline to be used at full capacity. The investment associated equals



GRAPH 4

US$12 million. It was taken from a standard cost of US$43 per barrel, for storage tanks at Galan station (Barrancabermeja refinery), times 200 thousand barrels of the new storage tank.

3-4: The second step is re-installing the Copey pumping station that used to work until expansions in the Barrancabermeja refinery made it useless. Likewise, to make it works, it is necessary to repair and change some sections of the pipeline. Re-installing the pumping stations cost US$15 million, and the repairs and changes of sections might be US$12 million. Thus, total cost is US$27 million.

4-5: The third step is homogenizing the Pozos Colorados – Galan pipeline. In its 503 km, the pipeline has four different diametres, 12,14, 16 and 20 inches (25), with pipes made of different materials. Then, rugosity is very high because of changes in size, jointions, and differences in materials. It is estimated the investments may reach US$25 million to

homogenize the pipeline changing critical sections with small diametre and lots of jointions.

5-6: Having done the previous steps, the last one is building a new pipeline next to the one already built. It is considered a 14 inches pipeline to add 50 TBD of importing capacity. According to the vice-presidency of transport of Ecopetrol (26) the cost of such new pipeline including all the items such as environmental costs, building, pipes, and the expansion of Ayacucho station could be US$100 million.

In order to set an expansion function for the Barrancabermeja refinery, it was necessary to simplify the process of petrol making. For instance, in real world petrol is a mixture of fifteen different blending components coming from different sources. However, as it can be seen in Diagram 7, there are only two components considered here, straight run

SCHEMATICS OF THE PETROL PRODUCTION PROCESS IN THE BARRANCABERMEJA REFINERY

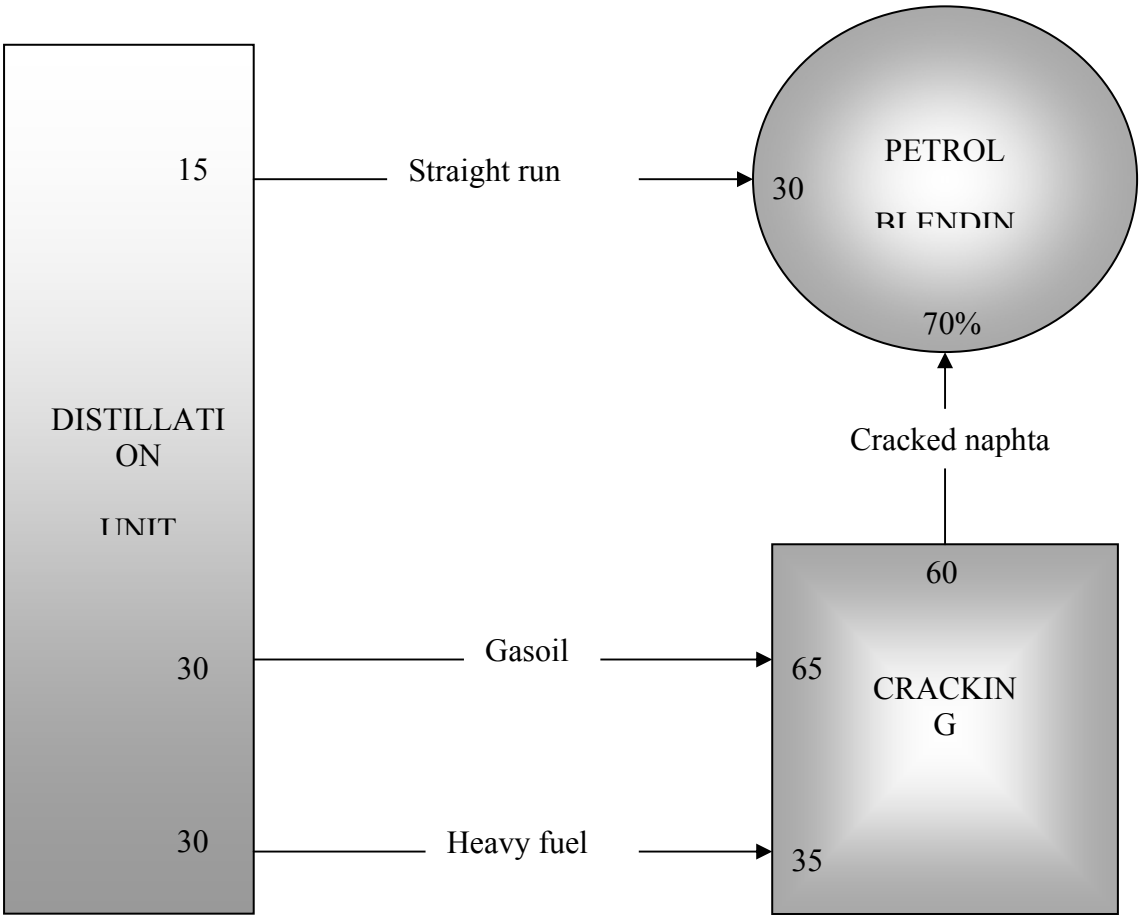


DIAGRAM 7

naphta (from distillation) and cracked naphta (from cracking). It is because these two components account for more than 95 per cent of the whole mixture, and because of that, they are the critical components in the investment decision-making.

Diagram 7 only shows the relevant elements in the petrol making of the Barrancabermeja refinery. It means that there are a lot of other products that are being neglected for this dissertation's purpose. For example, in the distillation unit, middle distillates like jet, kerosene and diesel are not depicted, in the same way, LPG coming from the cracking unit is not depicted either. Furthermore, in real world there is not only 'one physical' distillation unit and nor one cracking unit. But they represent a general scope of the process; in particular, emphasizing on modern units like the most recently built in the Barrancabermeja site. This consideration has been taken into account in the outputs of the distillation and cracking units. For instance, in the Barrancabermeja refinery there are cracking units as old as 30 years like the Model IV. It can not receive heavy fuel oils but only gasoils; consequently, it has a low conversion capacity. By contrast, the recently bought Orthoflow unit receives heavy fuel oils as an important share of its feedstock. Thus, it was considered high technology units rather than low (old units) because it is more likely that any project of expansion will get the available technologies in the market which tend to improve with time.

Distillation has two parts, atmospheric distillation and vacuum distillation. The first one is the most known and its capacity is associated with a refinery capacity, it is also called topping capacity. It works at atmospheric pressure and separate straight run naphtas, gases, jet, kerosene, diesel, gasoils and fuel oils. The separation is done because of their differences in boiling temperatures. In the second part, the heavy fraction, fuel oils, coming from the atmospheric tower passes through a second tower at vacuum conditions. It allows the recovery of light products from the heaviest stock.

The analysis starts from a given petrol demand. Then it is necessary to produce the two components that make petrol, straight run naphta and cracked naphta. In addition, it affects both, cracking and distillation capacities that must be able to produce these products. In this way, it is really important to identify the links between the components of the petrol making process in order to establish the magnitude required in expansions of distillation and cracking capacities. It can be seen in the following mathematical expressions:

From the petrol blending,

Cracked naphta = 0.70 petrol blend

Straight run naphta = 0.30 petrol blend

Feedstock of the cracking unit,

Gasoils = 0.65 Cracking capacity

Heavy fuel oils = 0.35 Cracking capacity

Output of the cracking unit,

Cracked naphta = 0.60 Cracking capacity

Output of the distillation unit,

Straight run naphta = 0.15 Distillation capacity

Gasoils = 0.30 Distillation capacity

Heavy fuel oils = 0.30 Distillation capacity

Having cleared the link between distillation and the blend; and between the cracking unit and the blend; now the problem is identifying the link between cracking and distillation. It will indicate how much distillation capacity should be built for a given cracking capacity to produce certain desired quantity of petrol.

Equalizing straight run naphta and replacing petrol blend,

Distillation capacity = 1.71 Cracking capacity

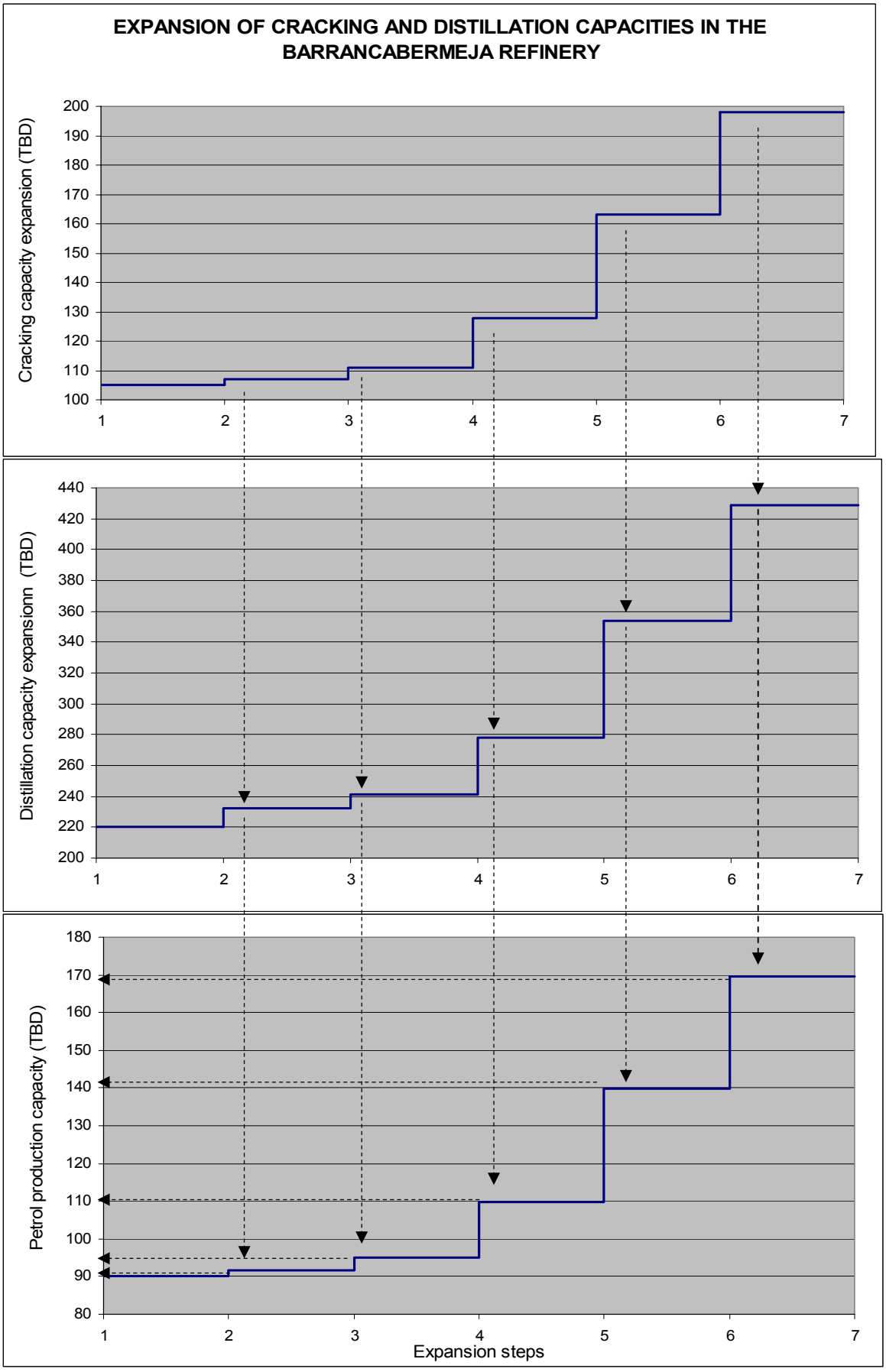
Equalizing Gasoils,

Distillation capacity = 2.11 Cracking capacity

Equalizing Heavy fuel oils,

Distillation capacity = 0.86 Cracking capacity

As can be seen, the critical element are gasoils, hence, in order to produce the gasoils that the cracking unit needs, distillation capacity should be at least 2.11 times the cracking capacity. In the same way, it is guaranteed that there will be more than enough heavy fuel oils and straight run naphta. This situation represents exactly what is happening in real world. The Barrancabermeja refinery has surpluses of straight run


EXPANSION OF CRACKING AND DISTILLATION CAPACITIES IN THE BARRANCABERMEJA REFINERY
Cracking capacity expansion (TBD)
200
190
180
170
160
150
140
130
120
110
100
1
2
3
4
5
6
7
Distillation capacity expansionn (TBD)
440
420
400
380
360
340
320
300
280
260
240
220
200
Petrol production capacity (TBD)
180
170
160
150
140
130
120
110
100
90
80
Expansion steps

GRAPH 5

naphta and heavy fuel oils that in fact are being exported. In Graph 5 is depicted the expansion function of the petrol supply capacity that depends on the distillation and cracking capacity expansion functions. It is important to notice that the distillation capacity expansion function depends on the cracking capacity expansion function. It was obtained from the optimum technical and economic way the cracking capacity can in fact be expanded. It might be needed, for example, only one barrel a day of cracking capacity under a 0.9 barrel a day increase in petrol demand, but technically there can not be an expansion that small in cracking units. In addition, it is assume that distillation expansions are more flexible than cracking expansion, consequently, it can be asserted that the former depends upon the latter. For calculating marginal investment in distillation capacity, it was assumed a general accepted one US$ million per thousand of barrels a day of distillation capacity. In the same manner for the cracking expansion steps, the figures were estimated looking at the Ecopetrol's development plans in refining for 1998-2010 (27).

1-2: Current capacity with nearly 100% utilization (from feasible)
2-3: It is the modernization of the Orthoflow cracking unit. It is a US$20 million investment.
3-4: It is the modernization of the UOP-I cracking unit costing US$22 million.
4-5: It is the decommissioning of the Model IV cracking unit and the replacement for a new one. It costs US$95 million.
5-6: From here onwards it will be new cracking unit for 35 TBD costing US$200 each.
6-7: It will be exactly the latter, a new unit of 35 TBD costing US$200.

It is important to notice that in order to only consider petrol-related returns real costs were reduced in the cracking and distillation processes by 40 and 80 per cent respectively. Hence, it should not be compute the whole cost of an extra distillation unit because it is not going to return its capital by only petrol sales, but by other oil product sales such as middle distillates, aviation fuel and heavy fuel oils. In the same way, cracking units get return on their investment from LPG, light fuel oils, and others product too. By contrast, return of investments in expansions of the petrol-importing pipeline will be obtained by only petrol sales because the pipeline is used only for carrying petrol. Therefore, by reducing cracking and distillation costs to find only the

petrol-related business, it will be possible to compare the refining business with the petrol-importing pipeline.

4.5. Constraints

According to the functions depicted in Graph 5, there are some boundaries for the LP model. Thus, variables fluctuate within a range as follow:

Petrol imported ≥ 0 TBD in any case it can be negative

Petrol imported ≤ 150 TBD maximum step of the importing pipeline function

Petrol refined ≥ 0 TBD in any case it can be negative

Petrol refined ≤ 169.7 TBD maximum step of the refining capacity function

Petrol demand ≥ 100 TBD today's demand is 130 TBD and it tends to rise

Petrol demand ≤ 319.7 TBD it is the sum of pipeline and refining maximums

Petrol imported + Petrol refined = petrol demand

Petrol importing pipeline capacity ≥ Petrol imported

Refining capacity ≥ Petrol refined

Expected payback period for marginal investments in refining capacity = 6 years

Expected payback period for marginal investments in petrol importing pipeline capacity = 3 years

4.6. Objective function and the algorithm

Finding the combination of the least cost under the given constraints

Minimization:

petrol refined x (refining cost + marginal investment of expansions in refining capacity = f(petrol refined))

+

petrol imported x (international price + marginal investment of expansions in pipeline = f(petrol imported))

The algorithm that represents the above concept in the spreadsheet is:

```
B9*1000*(B4+0.15/(B6*365)*((IF(B9/K25<1,0,1)*(J26+J40)*1000000/
((K26-K25)*1000))+(IF(B9/K26<1,0,1)*(J27+J41)*1000000/((K27-
K26)*1000))+(IF(B9/K27<1,0,1)*(J28+J42)*1000000/((K28-
K27)*1000))+(IF(B9/K28<1,0,1)*(J29+J43)*1000000/((K29-
K28)*1000))+(IF(B9/K29<1,0,1)*(J30+J44)*1000000/((K30-
K29)*1000))))
+
B10*1000*(B5+0.3/(B7*365)*((IF(B10/B25<1,0,1)*C26*1000000/((B2
6-B25)*1000))+(IF(B10/B26<1,0,1)*C27*1000000/((B27-
B26)*1000))+(IF(B10/B27<1,0,1)*C28*1000000/((B28-
B27)*1000))+(IF(B10/B28<1,0,1)*C29*1000000/((B29-
B28)*1000))))
```

B9*1000: petrol refined in barrels per day

B4: fixed cost of refined petrol at the Galan station in US$ per barrel

B6: expected payback period in years

0.15/(B6*365) factor to spread capital return expressed in US$ per day

B9: petrol refined in TBD

K25: present petrol production related to refining capacity

J26: Investment for first step in expansion cracking capacity

J40: Investment for first step in distillation capacity

1000000: It convert J26 and J40 from US$ million to US$

K26: present petrol production capacity plus the added due to the first step expansion

1000: convert K26 and K25 from thousand to single units

IF(B9/K25<1,0,1) it is 1 when refined petrol is higher than capacity, then, marginal investment of the step 1 in the refinery expansion takes place. Thus, it is taken the first step of the function.

The other part of the equation represents each step of the function for expansions in refining capacity. In the same way, the second part of the algorithm deals with the marginal investment of the petrol pipeline expansion capacity. It is important to highlight that numbers 0.15 and 0.30 of the factors to spread capital return were obtained from calibrating the algorithm in order to get real figures, hence, values within a sensible range, which offset financial consideration and the changing cost of money with time.

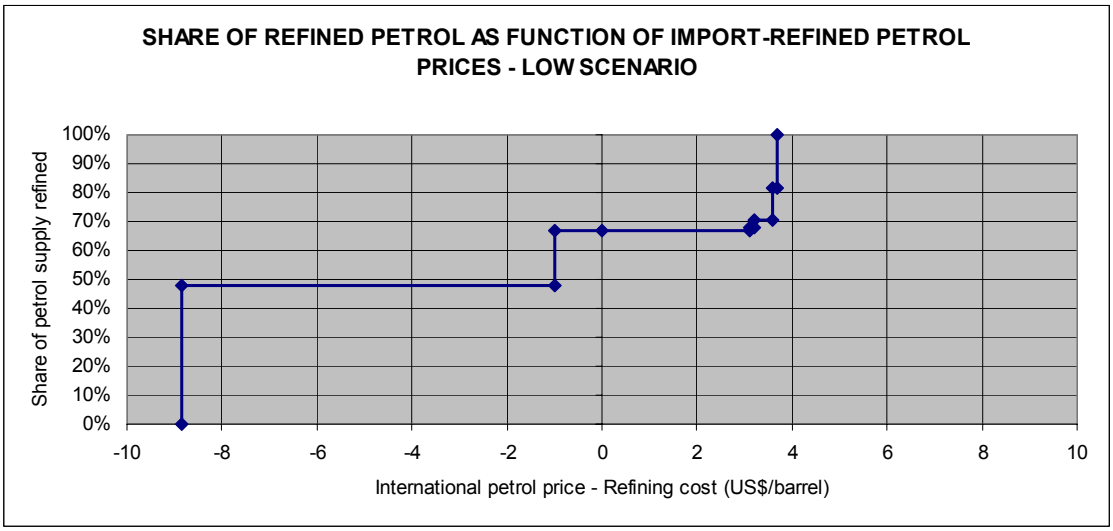
4.7. Results

There were three scenarios of petrol demand in 2010 considered at Galan station, a low scenario of 135 TBD, the Ecopetrol scenario (8) of 153 TBD, and a high scenario of 181 TBD. Standard conditions can be seen below.

LP MODEL - BARRANCABERMEJA REFINERY

Petrol Demand (TBD):	130	(100 - 319.7)		
Fixed cost of refined petrol at Galan station (US$/barrel):	25.00			
International petrol price at Galan station (US$/barrel):	25.00			
Payback period expected of marginal investment in refining capacity (years):	6	(6 years)		
Payback period expected of marginal investment in pipeline capacity (years):	3	(3 years)		
Petrol refined (TBD):	90		<= 169.7	>= 0
Petrol imported (TBD):	40		<= 150.0	>= 0
Total Gasolina (TBD):	130		<= 319.7	>= 0
Objective Function:	3,250,040	US$/day		
Marginal investment in refinery expansions (MUS$):	0			
Marginal investments in pipeline expansions (MUS$):	0			
Refining capacity added (TBD):	0	Total capacity (TBD):	220	
Cracking capacity added (TBD):	0	Total capacity (TBD):	105	
Petrol production capacity added at the Barrancabermeja refinery (TBD):	0	Total capacity (TBD):	90	
Petrol importing pipeline capacity added (TBD):	0	Total capacity (TBD):	42	

Apart from the constraints already explained, the first five lines represent the demand for a given scenario, the prices of petrol refined and imported, and the expected payback periods for marginal investments in expansion of both refining and pipeline capacities. As it can be seen in Graph 6, at parity of international petrol price and the cost of

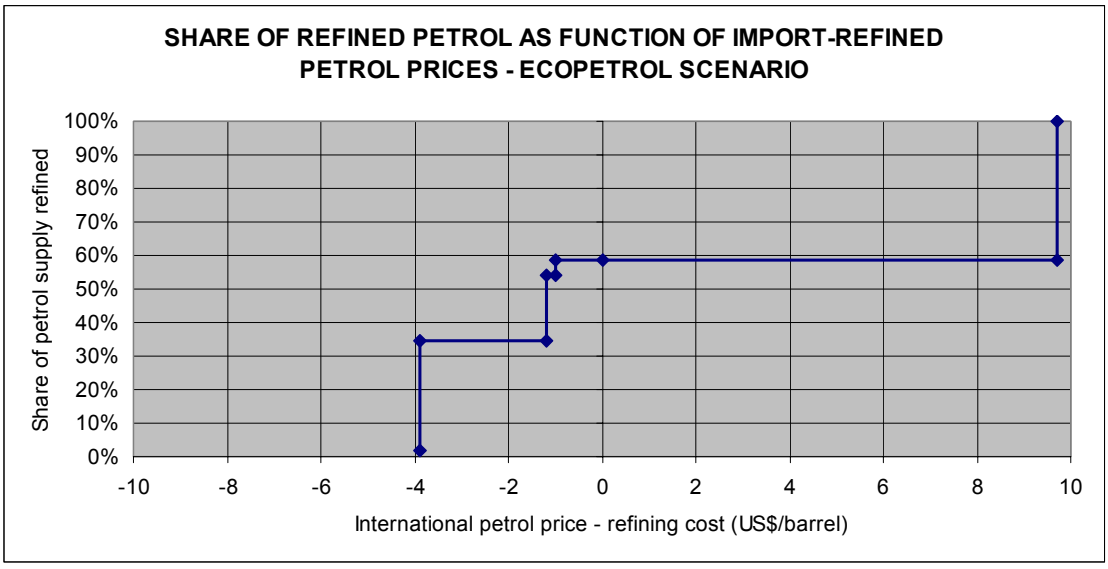


GRAPH 6

refining, the share of petrol supply by refining is almost 70%. However, as the refining cost increases in relation to the international petrol price, importing becomes more profitable than refining, therefore the share of petrol refined decreases. The reason why the line is not a continuos curve is due to the constraints, in particular, the expansion functions. For instance, in the first drop of the share of refined petrol, what is really happening is that, under such a difference of prices between refining and importing, going into the second step of expansion of the pipeline capacity is the best option. Thus, re-installing the Copey pumping station to increase importing capacity becomes a cheaper alternative than supplying petrol from refining. In addition, if refining gets even more expensive in relation to importing, then the share of petrol refined vanishes at a difference of US$8,84 per barrel of petrol. Consequently, at this point it is better supplying petrol by importing than by refining at the Barrancabermeja refinery.

Looking at the other way, as the international petrol price soars in relation to the refined cost to a US$3.10 per barrel difference, then it is worth undertaking the first step of expanding the refinery to produce more petrol inland than buying it abroad. As the price difference increases to US$3.2 per barrel, then it is worth going to step 2 in refining expansion and not even going to step 1 of pipeline expansion. Moreover, if such trend continue, it is worth undertaking step 3 in refining at US$3.6 per barrel difference, and lastly, at US$3.7 per barrel difference, it is worth not importing at all.

Graphs 7 and 8 show the tendency of the refined – imported petrol supply under the Ecopetrol (medium) and high scenarios of demand. As it can be observed, there are

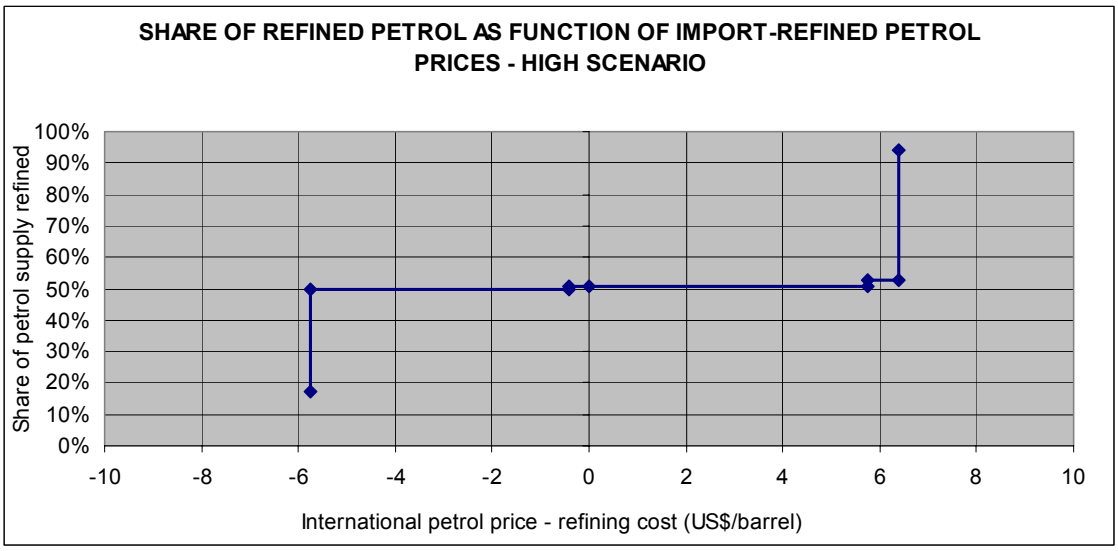


GRAPH 7

substantial differences between the relationship of the petrol refined share and the difference of refining and importing prices.

Under the low scenario the petrol-refined share is very sensitive to increases of the international petrol price, hence, when international petrol price rises it is not worth importing petrol any more, but refining inland. Contrary, the petrol refined share remain equal when refining costs increases up to a price-differential peaking US$9 per barrel.

By contrast, under the Ecopetrol scenario the share of petrol imported is more price-differential elastic than the share of petrol refined. It means that small increases in refining costs cause the share of refined petrol supply to plunge. Whereas, increases of the international petrol price do not augment the share of refined petrol until the price-differential reaches nearly US$10 per barrel. Lastly, the high scenario of petrol demand depicted in Graph 8 shows a balanced sensitivity of the refined and imported petrol share.



GRAPH 8

The least cost solution under the low and Ecopetrol scenario happen at parity of prices, hence, when the price-differential equals zero. The reason is because under such circumstances there is an optimum utilization of the infrastructure already built. Therefore, investing more to offset a big disruption in prices is not needed. However,

RESULTS SHEET

LP MODEL – BARRANCABERMEJA REFINERY

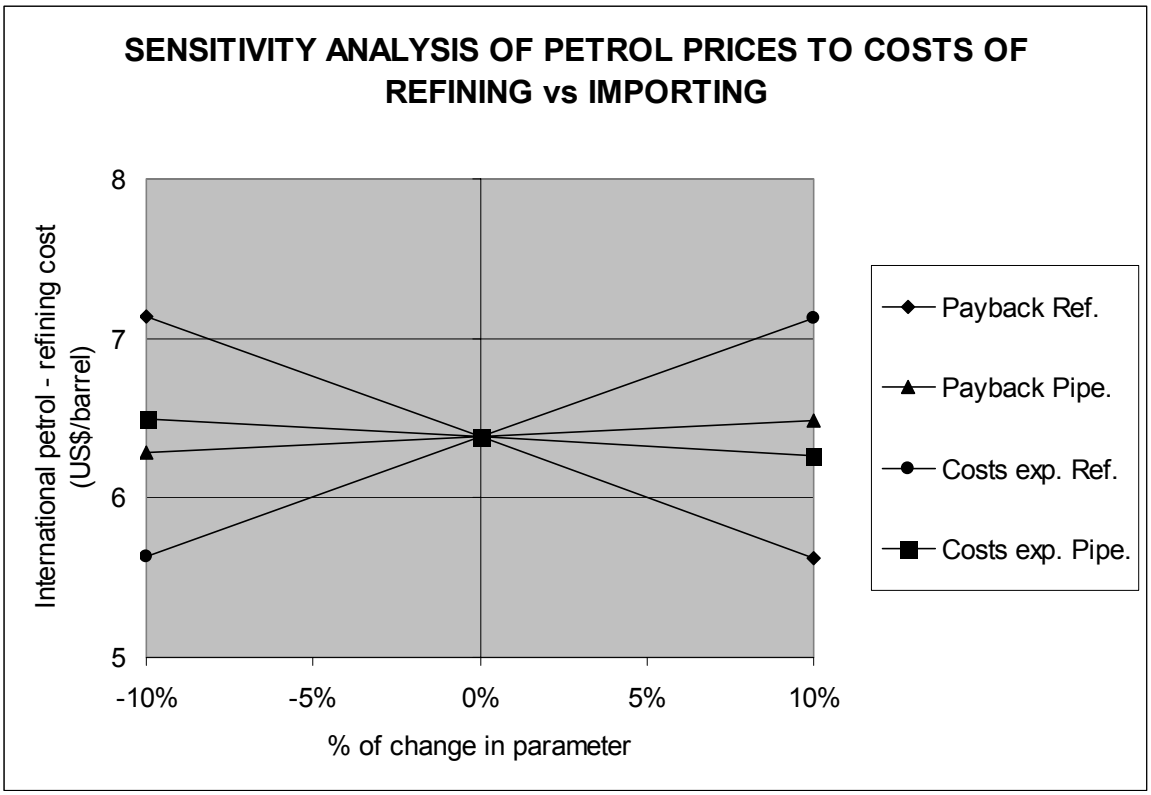
No	Petrol demand	Refining cost	International price	Price difference	Petrol refined		Petrol imported		Marginal Inv. in refining*	Marginal Inv. in pipeline*	Refining cap. added	Importing capacity added
	(TBD)	(US$/barrel)	(US$/barrel)	(US$/barrel)	(TBD)	(%)	(TBD)	(%)	(US$Million)	(US$Million)	(TBD)	(TBD)
Low Scenario												
1	135	25	25	0	90	67%	45	33%	0	12	0	8
2	135	26	25	-1	65	48%	70	52%	0	39	0	28
3	135	33.84	25	-8.84	0	0%	135	100%	0	151	0	108
4	135	25	28.1	3.1	92	68%	43	32%	14	12	12	8
5	135	25	28.2	3.2	95	70%	40	30%	29	0	21	0
6	135	25	28.6	3.6	110	81%	25	19%	94	0	58	0
7	135	25	28.7	3.7	135	100 %	0	0%	229	0	134	0
Middle scenario (Ecopetrol)												
8	153	25	25	0	90	59%	63	41%	0	39	0	28
9	153	26	25	-1	83	54%	70	46%	0	39	0	28
10	153	26.2	25	-1.2	53	35%	100	65%	0	81	0	58
11	153	28.9	25	-3.9	3	2%	150	98%	0	151	0	108
12	153	25	34.72	9.72	153	100 %	0	0%	364	0	209	0
High												

scenario												
13	181	25	25	0	92	51%	89	49%	9	79	12	58
14	181	25.4	25	-0.4	90	50%	91	50%	0	81	0	58
15	181	30.75	25	-5.75	31	17%	150	83%	0	151	0	108
16	181	25	30.75	5.75	95	52%	86	48%	29	81	21	58
17	181	25	31.38	6.38	170	94%	11	6%	364	0	209	0

TABLE 5 * Attributed to petrol making process (=0.45 total cost)

under the third scenario the least cost solution does not happen at parity of prices, but when the cost of refining peaks US$25.40 per barrel. This point is under the threshold in which it is not worth expanding refining to step 1, but increasing imports needless of expanding pipeline. These and more details can be observed in the results sheet, Table 6.

Because the price-differential of refined and imported petrol play a crucial role in the results already shown, it is important assessing what sort of inputs affect it. In this way Graph 9 depicts a sensitivity analysis of the most important variables that affect such price-differential of refined and imported petrol.



GRAPH 9

It can also be seen in Graph 9 that fluctuations in the costs related to the expansion function of the refining capacity have the most severe effect on the price-differential. In the same way, fluctuations in the expected payback period of marginal investments in expanding refining capacity considered in the model have the second most important effect on the price-differential. Contrary, changes in the equivalent variables related to the petrol importing have a little effect on the price-differential.

Further discussion about these results can be found in next chapter.

5. ANALYSIS AND DISCUSSION

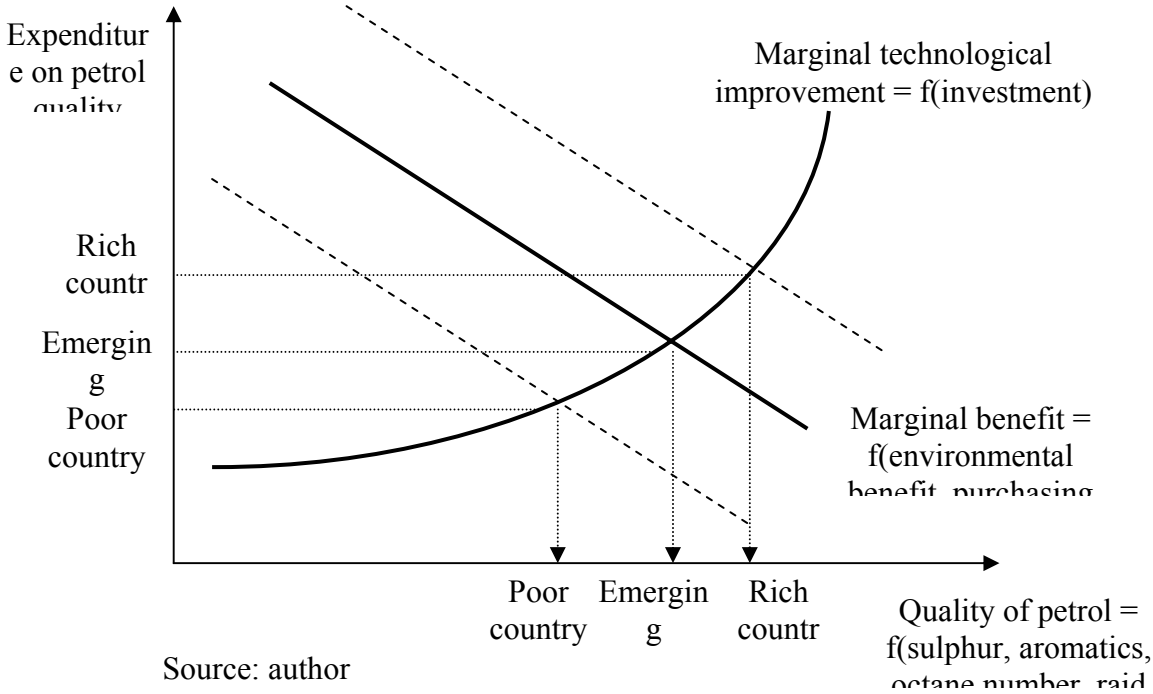
5.1. Institutional, political, technical, economic and environmental issues

5.1.1. Quality of petrol

One of the important issues in the Colombian petrol policy is the achievement of a certain quality that has yet to be defined. This is a trade-off between two major variables, the costs and the benefits. As is depicted in Graph 10, there is a point in which marginal technological improvement (costs) equals marginal benefits. The former depends on the amount of investment and the latter depends on the environmental benefits and the purchasing power of a nation.

Graph 10 points out that the richer a country, the higher the petrol quality. Although there might be exceptions due to regulated markets in some countries, it is true for the Colombian case. The reason is because in the planning of a country it should be taken into account its economic capabilities to pursue demanding targets. Hence, it would be nonsense to produce petrol of a quality as high as in Europe or the USA, because it would imply a greater effort for the Colombian people than for the Europeans or American in relative terms.

TRADE-OFF OF THE OPTIMUM PETROL QUALITY



Source: author

GRAPH 10

Examination of Graph 10 reveals that the right quality of petrol for Colombia should be in between the curve associate to a rich and a poor country. If on the one hand, there were no attempt to improve quality of petrol, then, there would be great costs associated to environmental effects as well as shadow costs associated with constraints due to a low quality of petrol. For instance, not being able to take advantage of the latest technologies in efficient motorcars owing to poor petrol quality.

One the other hand, there were heavy investment in acquiring the machinery required to produce petrol with a quality as high as the European or American petrol, then, it would be too costly for the Colombian people. Thus, people would be spending too much on petrol quality in relation to their income. Furthermore, there would be disproportion in the people's quality expenditure when compared to other goods. For instance, it would be nonsense to have the highest quality of petrol available, whilst not having enough clean water for public consumption. Development in a country should be proportionate to their priorities.

In light of the above dicussion, Colombia can be considered as having a good petrol quality relative to both its level of development, and its purchasing power. As was mentioned in section 2.3.2, Ecopetrol has taken important steps to improve petrol quality enhancing octane and reduce sulphur content. Therefore, in Colombia, improving petrol quality should not be a priority at the moment. It does not mean that this is not important, but that there are other priorities such as the administrative restructuring and the settling of a free market framework.

What it is really important is not doing anything else to improve the petrol quality in Colombia while the rest of the countries are actually making some progress as this would mean becoming further outdated in comparison to the developed world. If the government, based on the above criteria, focused more its role towards an administrator and a regulator in an open market, then, the market and its participants would trade the petrol with the quality demanded either from refining or importing.

5.1.2. Quantity of petrol

As can be seen in Appendix 4, there were three scenarios of petrol demand considered. The high scenario that implies a low substitution of petrol by any alternative fuel as well as a steady growth of income per-capita, the low scenario that implies a high substitution and an intermediate level. In other words these scenarios depend on the level of substitution to alternative fuels and the level of income that depends on the way the country develops. In Colombia there are two alternative fuels that might affect petrol demand: diesel and compressed natural gas. Although heavy transport is already using diesel, there are still very few diesel-fueled cars on the national fleet at the moment. In this way, there could be changes on the pattern of diesel demand as long as on the one hand, the petrol price continue to be higher than the diesel, and on the other hand car makers increase the number of diesel fueled cars on the basis of efficiency.

The government should play an important role in giving incentives for using diesel for two main reasons. Firstly, because it has been proven world wide that diesel fueled vehicles are more efficient than petrol fueled ones in two aspects; energy efficiency measured in amount of fuel consumed per mile and environmental impact due to less CO_2 emissions emitted per mile. Secondly, the Colombian refining capacity has a considerable surplus of diesel; this is the reason why Colombia exports nearly 12 TBD of diesel. Moreover, diesel is a more profitable product for Ecopetrol's refining industry than petrol itself. It can be seen in Table 6, in 1998 the net margin of diesel was actually higher than the petrol one within Ecopetrol refining industry. Hence, if the government supported the substitution of petrol by diesel, it would benefit the refining industry and the efficiency of private transport as a result of better performance and cheaper fuel.

The drawbacks of government attempts to promote dieselization involve an increase in the level of engine noise because diesel engines are noisier than petrol engines and further investment would be needed in the refineries to reduce sulphur content in diesel. In this way, if all costs are internalized, converting to diesel result in the advantages and savings hoped for.

The government should create a proper framework to allow competitors to supply diesel and natural gas as fuels for motorcars and internalize the environmental externalities by using diesel and compressed natural gas for vehicles. Thus, it will certainly require government intervention to avoid market failure in delivery of the least cost solution for fuel supply. For instance the 'Transmilenio' project of the capital city Bogota, which

intends to deliver a solution for largesale public transport in the main motorways, will provide incentives to car users if they switch from petrol to compressed natural gas. The plan is being pursued by the major of Bogota and is expected to be fully implemented within the next 3 years.

5.1.3. Tackling petrol smuggling

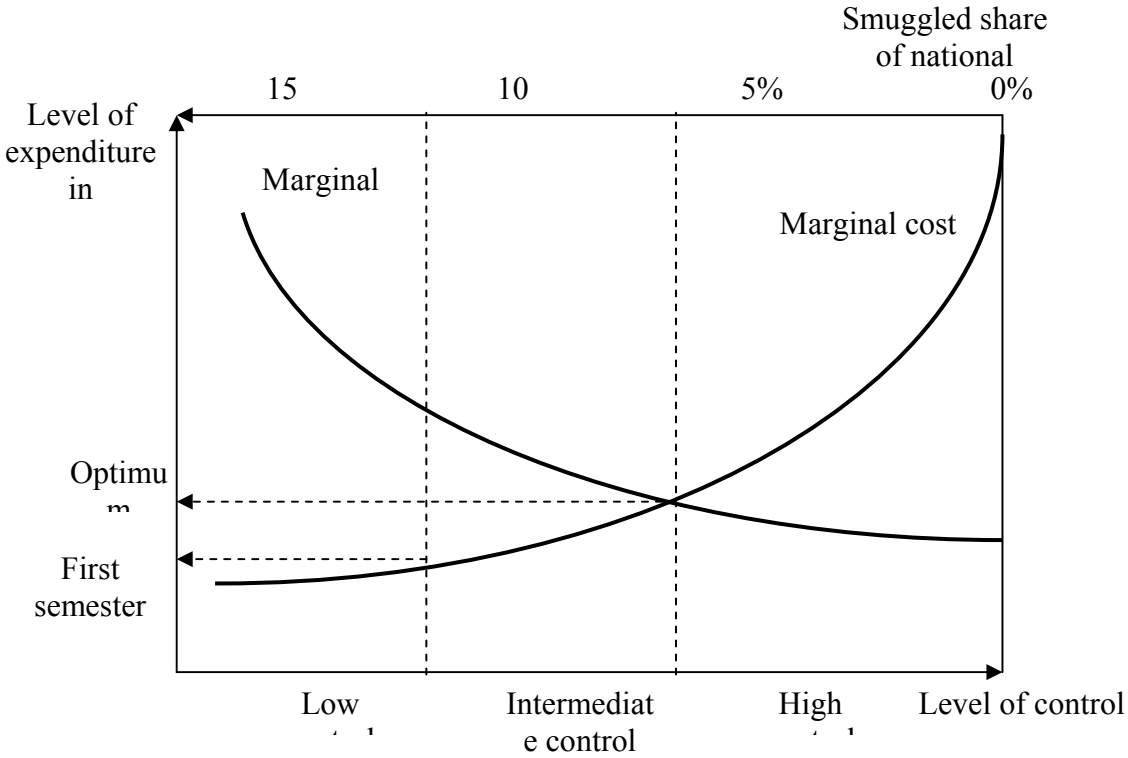
Petrol smuggling from Venezuela has always existed in Colombia due to the difference in prices. Although Venezuela has increased petrol prices, it is still one of the cheapest in the world, making it very profitable for smugglers to buy petrol in Venezuela and sell it in Colombia. Nevertheless, since the petrol price liberalization in Colombia in January 1999, smuggling has increased sharply because the difference in prices have further widened. This poses a serious problem for Colombia in many aspects. Firstly, the legal sector is significandly affected because it looses its market share, which may result in bankrupcy for many retailers. In addition, wholesalers are not encouraged to continue investing in expansions and sales are reduced for the petrol producer too, affecting the very tough business of downstream. For instance, smuggling recently resulted in the bankrupcy of the Tibu refinery, which is located in the North of Santander department by the Venezuelan frontier.

Furthermore, the state looses because it does not receive money owed as taxes on petrol which has been smuggled, and so the provinces are affected by a reduced market share. Furthermore, they can not get the municipality tax, which accounts for nearly 20 per cent of the petrol consumer's price, from the sales of smuggled petrol. Moreover, the final consumer is penalized because of lower quality of petrol. On the one hand, it is leaded petrol, and on the other hand it is frequently a blend of various types of petrol with a lower octane value.

The first lesson to learn is that the Colombian government should strengthen links with the Venezuelan authorities in order to establish better controls from the Venezuelan retailers. The second lesson is that the Colombian government should invest more on preventing petrol smuggling. A representation of the relationship between the level of expenditure in controlling petrol smuggling, the smuggled share of the market and the level of control is depicted in Graph 11. Within the first half of 1999, there was hardly any level of control over petrol smuggling, as the government did not have a high

enough expenditure in controlling petrol smuggling and therefore the share smuggled was as high as 10 – 15 per cent of the total national petrol consumption.

OPTIMUM EXPENDITURE LEVEL FOR CONTROLLING PETROL SMUGGLING



Source: author

GRAPH 11

From Graph 11, it can be seen that there is a lack of expenditure on he control of petrol smuggling. In this graph it is assumed that the level of expenditure is associated to the level of effective controls. Thus, the level of expenditure is positively related to the level of control.

The meaning of the graph is that there is a point at which the investment and the administrative and technical expenditure equal the opportunity cost of not expending that in the control of petrol smuggling. Hence, if there is a low level of control associated with a low level of expenditure, then, the government is actually losing money because it would get a greater marginal benefit per unit of marginal expenditure. In the same way, after the optimum point, if the government undertakes further expenditure, then it will not get a big enough marginal benefit to compensate such marginal cost.

Raising the level of control means increasing the policy controls. There are two main ways of policing the smugglers. First, traffic controls throughout the frontier to prevent' smuggler's trucks from entering the country; second, controlling petrol quality in stations to find out which retailers were involved in illegal business. The easiest way to do this is by testing samples in petrol stations in order to be sure that petrol is unleaded. Thus, if leaded petrol is found in a station, it means that the station is selling smuggled petrol given the fact that petrol legally distributed in Colombia is unleaded. Third, controlling the petrol flow from the producer or importer to the retailer, that is more precise accountability to wholesalers for controlling their retailers.

5.1.4. Petrol pricing

The liberation of petrol price in Colombia undoubtedly represents a step forward to a deregulated market with a more suitable environment for competition. Thus, the possibility of getting the least cost solution to supply petrol and thereby easing Ecopetrol's financial burdens. However, it has been widely proven that making structural changes in an economically weak country like Colombia could prove to be extremely costly in social terms. For instance, the abrupt opening of the Colombian economy carried out in the early 1990's is blamed resulting in bankrupcy for the agricultural sector which has been a principal employer for more than a century. Consequently, there was mass unemployment of people who participated in illegal activities such as guerrilla groups, smuggling, street violence and drug dealing. In the future, changes in the administrative and economic structure of Colombia must be undertaken because of the very high social susceptibility that may result in worsening the situation.

With regards to the social costs associated to shocks in the price of petrol the government faces a trade-off problem to tackle. On the one hand if the government is too protective, then there will not be a suitable environment for the free market to deliver the advantages of releasing the state from giving subsidies and bringing private competitors to improve the service for the consumer. On the other hand, if the government completely deregulates the petrol supply business, then sharp fluctuations of the international petrol price and/or rapid devaluations can result in huge social discontent which is manifested in strikes that could halt the economy.

In addition, fluctuations in the US Gulf Coast petrol price may be caused by local changes in the US and not global market changes although the US prices heavily affect regional petrol prices. For instance, petrol price could rise in the US Gulf Coast due to inventory variations associated to the season driving effect. In the mean time, there might not necessarily be the same fluctuations in other places like Venezuela, therefore the Colombian petrol price would be unnecessarily dependant on the US Gulf Coast price.

These reasons may justify setting a ceiling for price fluctuations to protect an unprepared country for the absolute free market as with the interventions of exchange rate by the central bank when disruptions occur. Similarly, these changes should be done with clear and stable rules to send a positive sign to private sector. The fact that the petrol price was not gradually liberalized and an unexpected sharp fluctuation in the exchange rate occurred forced the government to change the structure of the petrol pricing twice in less than three months.

5.1.5. Reliability of petrol supply

Reliability is a very important issue in the petrol supply chain, it does not depend only in infrastructure capacity like storage capacity, but in the logistic of the whole process. One of the most important advantages of being in a deregulated free market is that reliability is actually improved because each competitor in the market has to be reliable to avoid losing their market share. Thus, the government does not need to pay for building storage capacity, but play a regulating role in which gives the private competitor the signals for them to build the storage capacity at the production and wholesale level. This has not occurred in the case of Ecopetrol.

In the Colombian case there are three issues concerning reliability. Firstly the permanent threat posed by strikes by the trade union towards every step of the petrol chain. Secondly, inventories in the production and wholesale level are very low in comparison to the international standard. For instance, in the US it might be around 30 days whereas in Colombia it is about 7 days. The main disadvantage of this situation is that it provides relatively little flexibility in case of an emergency. Thirdly, unlike mature markets that have wide pipeline grids, in Colombia there is only one pipeline for petrol importation, and moreover, only one to supply Bogota, which is the capital city and accounts for nearly half the national consumption.

The most important feature of the logistic in the Colombian petrol supply, is that because there is only one importation pipeline, petrol for the south west of the country has to be shipped from the north coast, crossing the Panama canal and reaching the Buenaventura port in the pacific coast. From there, petrol is piped from the port to the Jumbo station, and then it has to be transported in trucks. Besides that, part of petrol consumption for this area of the country is piped from the north coast having to pass through many pumping stations and thus resulting in logistic difficulties. As a result the transportation of petrol to meet the demands of the south west of the country is expensive, eventhough there is considerable demand.

The real challenge for the government is making sure that the administrative restructuring that could bring various competitors to establish a cost-reflective business, should also improve reliability. Thus, releasing the immediate need for Ecopetrol to undertake further capital investment with hardly any return as in the case of the 'Bahia Malaga' pipeline project over the pacific coast. Tha Bahia Malaga project has been suspended due to public opposition to potential environmental impacts on the surronding forest. Further study needs to be done to establish whether building a new pipeline brings sufficient advantage to justify the investment and compensation for the environmental damage caused. Presumably, in this case the answer seems to be no, at least in the short term.

5.1.6. Reliability of petrol supply: Petrol imports vs. Petrol refined within Colombia

The strategy of refining that has to be pursued by Ecopetrol is a trade-off between quantity and quality of the product. Currently, the balance tend to be more of quantity than quality because the Colombian refining capacity cannot produce extra petrol (94-RON), thus Ecopetrol has to import 98-RON from abroad to blend it with other lower quality products to produce extra petrol.

One alternative available to Ecopetrol is continuing capacity expansion (quantity), which sacrifices quality. Owing to limited resources Ecopetrol faces the challenge of deciding whether to invest in quality and import higher quantities, or expand capacity and import lower quantities of a high quality octane enhancer additive just as it is doing at the present moment.

Looking at the perspectives of being in an open market it can be asserted that if the import share of petrol consumption in Colombia rises, it will not mean reducing reliability. Correspondingly, the 80 per cent market share (8) targeted by the Vice-presidency of Refining and Marketing ought to be outdated. The reason is because it might be a barrier to finding the least cost solution delivered by a market-guided business. In other words, It should be clearly understood that if under certain circumstances it is more convenient to supply petrol through importation than by refining, it will not necessarily be a threat for the reliability of the petrol supply.

There are cases throughout the world which support this position, for instance, Japanese energy imports account for 98 per cent of its national consumption and Japan is the second largest economy in the world. Certainly, the fact that it has to import energy does not poses a threat or a terrific disadvantage for its economy. It is simply a matter of management.

Overall justifying a minimum refined market share for meeting petrol demand might be related to economics reasons like being able to take advantage of economy of scale, but it must not be linked to reliability of petrol supply.

5.1.7. Economy of Ecopetrol refining

The need to modernize the Barrancabermeja refinery is not inspired simply by the need to meet international standards, but also to improve its profitability and thus its economic viability in the long term. Modernizing the refinery in technical terms means raising the level of conversion of the refinery, and incorporating new equipment to extract products of higher value from the process (light products) and less cheap ordinary products (heavy products).

It follows then that, the level of conversion should be increased because light products have a higher added value than heavy products, therefore, the higher the level of conversion of the refinery, the wider the gross margin (Diagram 4). Consequently, the refinery becomes more profitable. It can be seen in Table 6 the average net margins of Ecopetrol's main products in 1998 proved that the light products, petrol and diesel, are profitable, whereas the heavy products, fuel oils, etc, result in losses.

NET MARGINS OF ECOPETROL MAIN PRODUCTS
1998 $Colombian

LPG	PETROL	DIESEL	FUEL OILS
(151)	263	350	(209)

Source: (10)

TABLE 6

Examination of Table 6 indicates that if Ecopetrol were to increase the level of conversion of its refineries, it would be improving profitability of its refining business. Although this should be done, there are uncertainties that might not make this analysis true once a high level of conversion has been achieved. For example, there is a low difference of petrol prices between high and low sulphur petrol due to excess capacity installed of desulpherizers in the US. Thus, when the modernization reaches a high level, it may or may not be justifiable to upgrade from the economic viewpoint. But as it has been stressed, it might be true once reaching a high level of conversion, therefore, modernization in the Colombian refining capacity seems to be something that has to be done sooner or later.

5.1.8. The link between good management and reaching Benchmarking targets

As has been stated Ecopetrol's economic performance is positively related to the technological improvements it undertakes. In the same manner, such relationships work as long as there is a suitable administrative framework in place. Put another way, there are three issues positively related to one another that are crucially important for Ecopetrol's future, they being the economic performance, the technological upgrade, and the administrative restructuring of the company.

Amongst the three aspects already mentioned, the administrative restructuring is possibly the most urgent because it heavily influences the other two aspects. If there were technological innovations without administrative restructuring, then, the economic performance might decrease. By contrast, if the governmental efforts were focused on administrative restructuring, then the technological implementation would follow and as a result the economic performance would improve.

Furthermore, some of the most important variables that directly affect Ecopetrol's improvements in economic performance depend entirely on the administrative restructuring. For instance, reducing labour costs by having more automation with fewer but better skilled employees improves maintenance and saves costs per unit of output. In the same manner it allows increasing the utilization level of the refineries and in general improves the infrastructure making it possible to further cut costs per unit of output.

All in all, administrative restructuring in Ecopetrol is the highest priority in the path of improving its performance from both the technical and the economic viewpoint.

5.1.9. Macroeconomic considerations

One of the most important considerations that have to be taken into account in re-defining the Colombian petrol policy is that success not only depends upon restructuring the companies related to the sector, but adopting reforms at every level of the state. Thus, even if petrol is being supplied by the monopoly of Ecopetrol (state-owned oil company), success cannot be guaranteed unless there are changes in other entities.

Stability is an absolutely crucial feature of an environment suitable for long term planning. In unstable economies it is really difficult to stabilize the conditions for a competitive market-based delivery of services and goods. In this way a clear and stable taxing policy is required, Colombia should try to extend the life of its regulations in order to allow entrepreneurs the opportunity for consistent planning in the long run. For instance, the importation pipeline fees and the regulations regarding wholesale should be stable in the long run. When there are changes underway, foreign companies lose confidence in the country and move their business to another country with better stability. In this way Colombia loses out an opportunity of the benefits given by the multinationals 'know-how', technology and capital. Similarly, the country loses the pressure of a competitive market that forces companies towards greater efficiency which delivers the best cost-benefit solution for the consumers.

At the national level issues such as interest rates, inflation and the exchange rate play a significant role in attracting foreign investment. For instance, Brazil had a 30 per cent devaluation of its currency within two weeks of January 1999. As a consequence a great deal of the foreign investment was suspended as their indebtedness in hard currency

became more expensive. Because of those reasons, it is important to notice that a successful macroeconomic management of both fiscal and monetary policy might represent the difference between success or failure in the opening of the petrol policy in Colombia.

5.1.10. Self-sufficiency in petrol supply vs. self-sufficiency in oil supply

Regarding budget constraints there is a trade-off situation in defining the oil policy in Colombia. On the one hand the government may put all its efforts in the upstream business looking to guarantee oil sufficiency for the nation. Thus, most of Ecopetrol expenditure goes to exploration, exploitation and infrastructure. On the other hand, the government may go downstream guaranteeing petrol supply which locally refined at the expense of adding more oil reserves or further time of oil-self sufficiency.

There is no doubt about the fact that at the present moment the government is correctly focusing upstream instead of downstream. The macroeconomic consequences of being net oil-importer are much greater than the impact of being net petrol-importer. One reason is because in the former case there are huge amounts of money that have to be spent by the government which causes the fiscal deficit to soar. Whereas in the latter case, the government has net surpluses as it has been shown that the refining margin is very small in comparison to the producer take (Diagram 2).

Moreover, the main reason is just because the upstream business is more profitable than the downstream. It means that selling crude oil is better than selling petrol. The reason lies on the risk associated with the investments. In Colombia for instance, the likelihood of finding petrol in a drilled well is about one out of five, or in other words, 20 per cent. That means than 80 per cent of the cases where there are investments in exploration result in no return at all. Conversely, the refining business has a very low risk but its margins are too thin.

For the reasons reviewed above, it seems necessary to open up the oil industry in both the upstream and the downstream markets to foreign companies. Neither the government nor Ecopetrol alone are capable of raising the capital investments required to speed up the modernization of the oil industry in Colombia in order to take advantage of its natural

resources. Calling on foreign capital, 'know-how' and technology is be simply an imperative for Colombia and Ecopetrol.

5.1.11. Trade off between importing costs and level of efficiency of Ecopetrol

Looking at the advantages and disadvantages of Ecopetrol refining capacity in a global market perspective, it can be asserted that unlike the Cartagena refinery, the Barrancabermeja refinery has a very important competitive advantage due to its geographic position, in the centre of the country. It gives the refinery the possibility of being very near the demand centre located mainly in Bogota.

According to Diagram 6 of section 4.4 the importing costs for petrol imported is roughly US$ 3.45 per barrel, of which US$ 1.6 per barrel represents government taxes, the importing tariff and the 'Timbre' tax. In other words, 47 per cent of the present petrol importing costs is taxes. It means, that the Barrancabermeja refinery is actually being protected from foreign competition because anyone who wanted to import petrol has to pay not only real costs of transportation, pumping and storage facilities, but also taxes of which tariff is more than 90%.

Now, it sounds sensible regarding the smoothly changes that have to be pursued in exposing the Barrancabermeja refinery to competition; hence, it is important to provide the refinery enough time for making the adjustments and the restructuring needed to become competitive. Similarly, certain levels of taxing should be associated to possible shadow costs or externalities, which the free market fails to consider, such as environmental pollution in the petrol handling or the opportunity cost of making employees redundant because of the level of importing at the expense of refining.

In the end the precise question of how much to protect Ecopetrol from foreign competitors by means of the importing tariff is yet to be found in further studies. But the concept is clear, it should not be too much that prevents healthy pressure being exerted on Ecopetrol by foreign competition, and not too little to bring the Barrancabermeja refinery to bankruptcy without having given it the chance to make the changes and create significant social cost. In a paper thin margin business like refining, the geographic location is very important, and thus, it is worth going forward with plans for the Barrancabermeja refinery.

5.1.12. How Ecopetrol and the country may benefit from losing market share due to competition?

The advantage of having 100 per cent share in the market is that being bigger brings benefits from economy of scale and profits can stay within the country. However it has been proved that these arguments turn out to be pure theory in the real world.

In fact, a monopoly state-owned oil company like Ecopetrol does not takes advantage of its size for having economy of scale and being more profitable. Actually, it produces losses in refining, thus in economic terms it might be better not being in the refining business unless structural changes happen.

As a result, by losing market share the government is benefited because of cheaper petrol might be delivered to the consumer. There are also two other advantages, firstly, because the government releases its responsibility of being the only petrol supplier, it can then focus on adding reserves in the upstream sector for guaranteeing long term oil sufficiency. Secondly, by not being the only supplier, the government can actually reduce the threat that the trade union poses to the petrol supply reliability.

5.1.13. Why wholesalers might be interested in importing their own petrol?

Given the very difficult global environment of the refining business and the significant competitive advantage that the Barrancabermeja refinery has, it is interesting to speculate about why a private company might be interested in importing petrol.

The first reason is because they can deliver imported petrol more cheaply than their counterpart's Ecopetrol, due to added value for being vertically integrated. The second reason is because they want to gain market share in downstream business as a worldwide or regional strategy. Thirdly, although not true for the Colombian case, it is worth mentioning, companies go downstream in some countries as a step towards going upstream because they find it easier to do so as state-owned oil companies normally protect the downstream businesses less than they protect the upstream.

5.1.14. Institutional and political strategy for Ecopetrol

Regarding ownership there are three possible ways Ecopetrol can adopt for its restructuring programme towards running a more efficient company, privatization, mixed capital or remain completely state-owned. As was already discussed privatization is the least convenient at the moment not only due to the massive opposition, but because the company is not attractive to foreign investors given the gravity of its administrative and economic problems.

Remaining state-owned could make it more difficult to carry out the administrative restructuring needed by Ecopetrol, as well as for obtaining the economic resources needed for the investments required. For the above reasons undertaking a mixed solution, like Petrobras and other state-owned oil companies (chapter 3), might be the best option for Ecopetrol.

The most urgent step of Ecopetrol restructuring should be finding a way under which Ecopetrol can obtain administrative autonomy and long term planning, thus, guaranteeing stability for the CEO and a merit-based promoting system. It would involve reforms from congress to make regulations for electing CEOs for fixed periods withdrawing the total dependency on the president, and, providing Ecopetrol with more independence and autonomy than it has had before.

In the issue of whether being vertically integrated or being unbundled there should be freedom for Ecopetrol's own decision. If there is a policy towards cost-reflecting business and free market involving new competitors, it would make nosense placing constraints on Ecopetrol such as prohibiting its participation in the petrochemical industry, even if it improves its profitability.

Undertaking deregulation in the petrol supply chain means that Ecopetrol should be allowed to be managed as if it were a private company seeking for improvements in competitiveness as well as getting economic resources from selling shares. In this way, Ecopetrol should be taken to the listing into the stock exchange market issuing shares to be bought by privates.

5.1.15. How to deal with the trade union USO

If there is something true about the USO union is that its influence on Ecopetrol performance has not benefited the state-owned oil company in the last decades. Although the Ecopetrol employees are amongst the best paid within the Colombian state-owned companies, they are always struggling to gain more and more benefits without any committment to improve their own performance. It is common knowledge that each time the government meets the unions to agree the increase in the minimum wage, the USO union asks for the highest rate for their workforce. The union takes advantage of the political susceptibility of the government when making deals

However, it is important to highlight that the union is not the only reason to explain the lack of competitiveness Ecopetrol currently has. It is the administrative structure and mostly the political influence that for years have prevented long term planning in Ecopetrol, and politician have conceded too much to the union to avoid unpopularity looking after their own political interests.

There are many possible ways to control abuses of the trade union. The radical solution is a military containment as was implemented in Singapore a few decades ago with great success in the long term. However, it seems to not be convenient in Colombia, first because the government should pursue peaceful means under the universal declaration on human rights, and second, because in practical terms it would be extremely costly due to the fact that the USO union has become a very powerful trade union. It is capable of threatening the economic stability of the state because of its strategic influence on the operation of Ecopetrol's infrastructure. It is believed that the union has been linked to extreme-left rebels that bombed the oil pipeline about 600 times in the last ten years, which equates to more than once a week for ten years. Also, there are employees linked to people who illegally perforate the pipelines to steal the petrol.

The challenge for the government in relation to Ecopetrol's trade union is trying by all peaceful and diplomatic means to make the union members aware that they need to make sacrifices to improve Ecopetrol economic performance because otherwise its long term survival could be endangered. Likewise, the government should make the union members aware that the company is owned by the whole nation and not by themselves. Thus the best way of getting social benefit from the company is not by creating bad businesses favoring only employees but by re-orientating the Ecopetrol vision towards profits and competitiveness. By the same token, it is really a challenge to make the

unionist understand the advantages and gains that the company can actually obtain by making strategic alliances and joint ventures with other international corporations.

5.1.16. Environmental and social aspects

Since law 99 was issued in 1993, Colombia has made substantial progress in settling an appropriate legal framework to protect the environment in industrial processes. There are regulations for solid waste disposal, liquid effluents and gaseous emissions. However, there is still a lack of specific regulation for certain sectors, for instance, although regulations in the upstream business of the oil industry are developed and implemented, to a certain extent, the downstream business lacks specific legislation and in particular, the refining industry.

In other words, there is much tougher environmental regulation in oil exploration and exploitation than in the refining and distributing business. Correspondingly, the state has been softer with state-ruled companies than with private ones, resulting in no benefit for the nation. Because of that it is very important to match the level of legally binding accountability towards the environment between state and private companies. This is not just looking at creating a more mature market that bring its advantages to the country, but also in creating a way in which the citizens will be benefited by sending the same signals to the market for protection of the environment.

Paradoxically in the Colombian petrol supply chain the most important environmental impacts are to be tackled by controlling both terrorism and perforations on the pipeline grid. Furthermore, Ecopetrol should pursue benchmarking targets for environmental impacts of its refineries in order to monitor emissions to the air, water and soil. In particular, making sure that the Barrancabermeja refinery does not affect the drinking intakes downstream in the Magdalena River.

Apart from these specific issues, the main challenge of the government should be finding mechanisms for internalizing environmental externalities in the petrol supply chain, for instance, setting up a special tax relief for projects related to using alternative fuels like liquid natural gas for motorcars that are more environmentally friendly.

5.2. LP model result: characterization of each of the three schemes

5.2.1. Scheme 1 Expanding Refining Capacity

As it can be seen in Table 5, for the low scenario of petrol demand expanding only refining capacity became the optimum alternative if the price differential expected (international petrol price – refining cost) average US$3.2 per barrel or more until 2010. Hence, if petrol imported at Galan station is expected to cost at least US$ 3.2 per barrel on average in the next 11 years more than the cost of refining, then it is worth only expanding the Barrancabermeja refining capacity and not expanding the pipeline at all. Now, taking into account the US$3.45 per barrel importing cost seen in Diagram 6, the US$3.2 per barrel price differential means that the refining cost should be US$0.25 per barrel no greater than the international petrol price for the period 1999-2010 in the US Gulf Coast (benchmark). It is assumed that the imported petrol comes from the US Gulf Coast (benchmark). This is illustrated in the following Diagram 8.

Assuming that the importing costs remain unchanged, the consequences for the Barrancabermeja refinery of this condition is that if it is able to produce petrol at a cost not greater than US$0.25 per barrel of the cost of a benchmark refinery. Then it will not be worth expanding the pipeline, but just the refining capacity as is shown in lines 5, 6 and 7 of Table 5. This is a really optimistic case, because it would imply that efficiency in the Barrancabermeja refinery would almost reach that of the benchmark. Consequently, it is very likely that under this scenario, expansions in the Pozos Colorados – Galan pipeline will be needed.

PRICE DIFFERENTIAL IN LOW SCENARIO EXPANSION ONLY IN REFINING

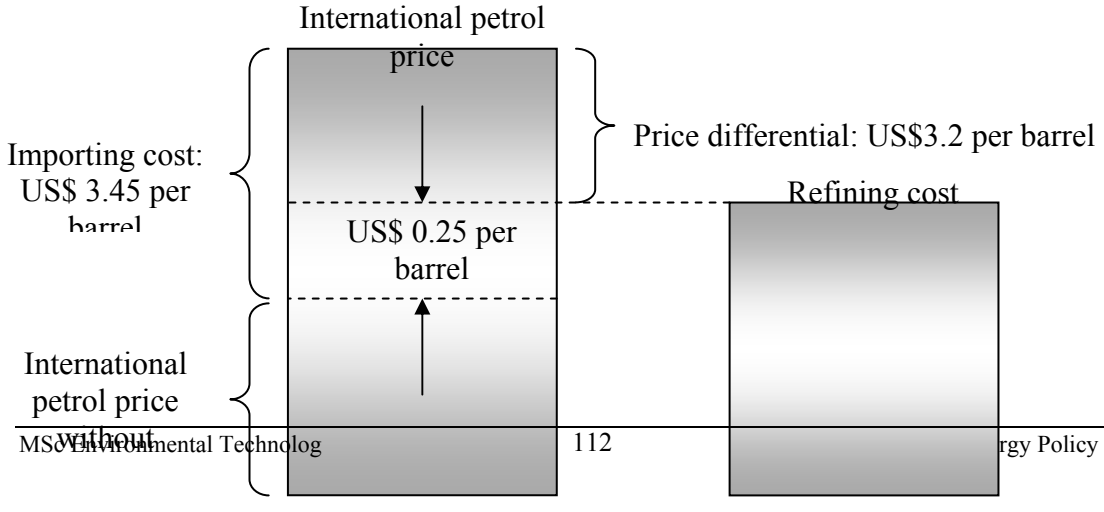


DIAGRAM 8

It can be asserted that as importing costs increase, then the price differential increases by the same quantity. It means that the Barrancabermeja refinery could be less efficient producing a more expensive barrel of petrol, but is still worth expanding the refining capacity instead of expanding importing capacity (pipeline). It is also true the other way round, as importing cost decrease, then, refining cost of the Barrancabermeja refinery face more direct competition from the US Gulf Coast. Now, looking at the structure of the importing cost in Diagram 6, it can be observed that almost half of such value is actually taxes for the Colombian government, the tariff and the 'timbre' tax. It means that in today's importing cost structure, the government is protecting the Barrancabermeja refinery from facing straight competition from the US Gulf Coast. Consequently, the higher the importing cost (taxes plus direct costs), the less efficiency required from the Barrancabermeja refinery to hold its market share.

However, stability in the importing cost is crucially important if the government were to attract private competitor to supply petrol. Thus, if the government changes frequently the importing costs, it will send signals to discourage private involvement in the business because of distrust in long term planning. For instance, in June 1999 as devaluation increased and the international petrol price soared too, the government was forced to cut the tariff by 7.5 per cent from 15.0 percent in order to avoid further increases in the consumer's price (52). It might have been a sensible measure to buffer petrol price protecting the local refining industry, but it was an antecedent that may produce distrust in legal stability.

Looking at the ECOPETROL scenario the price differential is US$9.7 per barrel (line 12 in Table 5), from which it is worth expanding only the refining capacity. As can be seen in Diagram 9 the situation is the opposite for the low scenario. Hence, the refined petrol at the Barrancabermeja site should be at least US$6.25 per barrel cheaper than the international price (regardless of importing cost) to justify expansion only of the refining capacity. Whereas in the previous scenario it could have been US$0.25 more expensive per barrel.

PRICE DIFFERENTIAL IN ECOPETROL SCENARIO EXPANSION ONLY IN REFINING

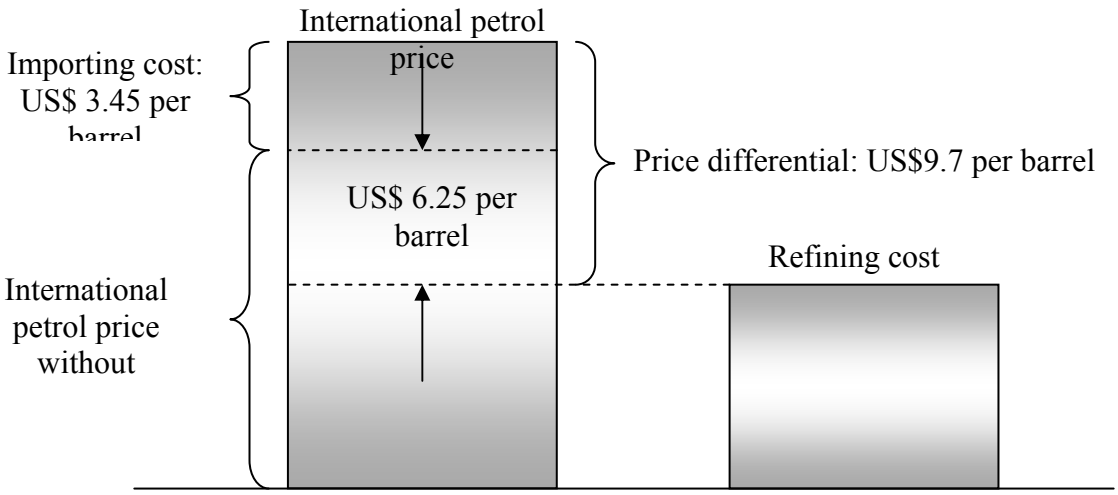


DIAGRAM 9

It means that if petrol demand rises as the ECOPETROL's scenario for the next 11 years, the need to expand the pipeline capacity will be virtually unavoidable. As can be seen in Table 5, at parity prices (price differential equals zero) the optimum share to meet the demand is not in expanding the refining capacity but expanding the pipeline to step 2 as depicted in Graph 4. In such event, it is worth building the two storage tanks and re-installing the Copey pumping station in order to take advantage of the maximum pipeline capacity.

In the high scenario the price differential to expand only refining capacity as the optimum augment in capacity is US$6.38 per barrel. Thus, conceptually it is a similar situation to the ECOPETROL's scenario of demand but with different figure. Hence, under this scenario the Barrancabermeja refinery should be able to produce a barrel of petrol US$2.93 cheaper than a US Gulf Coast refinery to justify only expansions in its refining capacity with no expansions in the pipeline. Clearly, in practice it means that expansions in the pipeline capacity are unavoidable.

Overall this scheme of only expanding refining capacity seems unjustifiable because it would almost imply either a better performance of the Barrancabermeja refinery than its benchmark, or a sharp increase in import cost caused by a stricter taxing policy to protect local refining.

5.2.2. Scheme 2 Expanding Petrol Importing Capacity

As a result of the fact that supplying petrol is a trade-off between refining and importing, it is logical to expect that justifying expansion in the petrol-importing pipeline has the opposite implications of the previous section. Indeed, looking at the low scenario in Table 5, it can be seen that when the refining cost is US$8.8 per barrel more expensive than the international price (Diagram 10), then it is justifiable to supply petrol by imports and not by refining. In this case it is worth expanding the four steps of the pipeline capacity depicted in Graph 4. It would imply that a barrel of petrol refined in Barrancabermeja should cost at least US$8.8 more than an imported barrel of petrol to justify decommissioning of the refinery. Furthermore, if discounting import cost, it would mean that the price difference between the Barrancabermeja refinery and the benchmark is US$11.25 per barrel. If considering a US Gulf Coast petrol price of US$25 per barrel, the Barrancabermeja refinery needs to produce a barrel as expensive as nearly 50% that of the international price to justify not expanding the refining.

Looking at the ECOPETROL's scenario the price differential is - US$3.9 per barrel. Thus, if the Barrancabermeja refinery produces a barrel at least 25% more expensive than its benchmark, then it is justifiable expanding only the Pozos Colorados – Galan pipeline to meet demand by imports (line 11 Table 5). In this scenario, things are much tougher than in the previous for the refining alternative. It means that in case of facing competition the Barrancabermeja refinery has to be reasonably efficient in comparison to its benchmark in order to be worth refining instead of importing. Likewise, the public regulator plays a very important role due to the fact that its taxing policy on import cost can be decisive in justifying imported and refined share. Diagram 11 shows this scenario in which the optimum differential price justify expansions only in the pipeline.

PRICE DIFFERENTIAL IN LOW SCENARIO EXPANSION ONLY IN PIPELINE

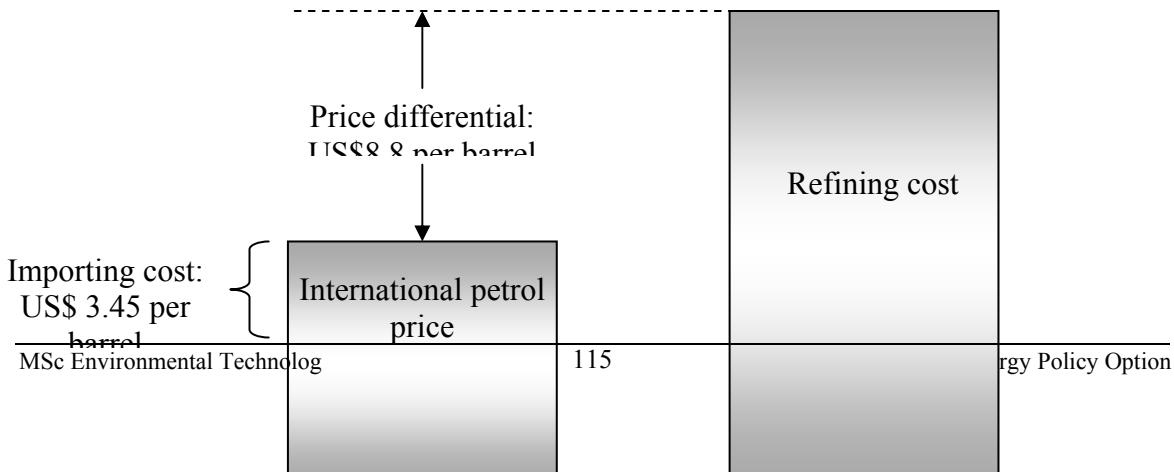


DIAGRAM 10

PRICE DIFFERENTIAL IN ECOPETROL SCENARIO EXPANSION ONLY IN PIPELINE

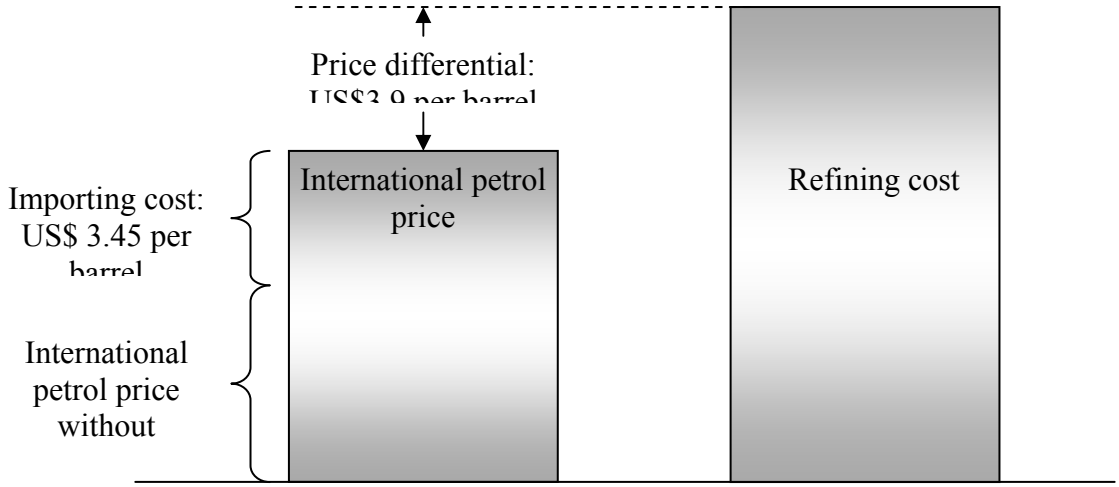


DIAGRAM 11

In the high scenario maximum expansion of the Pozos Colorado – Galan pipeline is justified when the refined cost is at least US$5.75 per barrel higher than the international petrol price. Therefore, if the petrol refined cost at least 40% more than that of the benchmark, then, it would be worth expanding only the pipeline. Now, if there were parity of prices for the next 11 years the refining capacity would be worth expanding up to the first step (Graph 5). But if the refined cost were to be as little as US$0.4 per barrel more expensive than the international petrol price at Galan, then, it would be worthless expanding to the first step.

According to this scheme, expansions in the Pozos Colorados – Galan pipeline are very sensitive to higher prices of petrol refined in relation to international price. It is clear that summarizing the results of the first two schemes under the three different scenarios of petrol demand, expansions in the Pozos Colorados – Galan pipeline are more likely than expansions in refining capacity.

The last statement seems to reflect the fact that if there were suitable conditions for a free market and almost perfect competition, it would be easier to import petrol from a benchmark company in the US Gulf Coast than refining within Colombia. Moreover, the government has a significant capability of balancing the supply share by taxing the importing cost. Likewise, the more efficient the Barrancabermeja became, the more justifiable the expansion would be in refining rather than expansions in the pipeline alone.

5.2.3 Scheme 3 Combination of Both

As it can be seen in Table 5, the least capital-intensive solution to meet petrol demand in 2010 happens when there is parity of prices between petrol imported at Galan station and the refined cost in the low and ECOPETROL's scenario. At parity of prices the low scenario of petrol demand for 2010 is met by expanding the pipeline to the first step, thus building storage capacity at the Galan station. It will make possible to use full capacity of the Pozos Colorados – Galan pipeline. It would be the cheapest way of meeting demand in 2010.

In the ECOPETROL's scenario the cheapest way of meeting the 2010 demand would be by expanding the pipeline to the second step (Graph 4), which means not only expanding storage capacity at Galan station, but re-installing the Copey pumping station. It is interesting to see that this will not require major investments, only investments to the importing infrastructure in order to be able to use it at the highest utilization level possible.

Contrary to the previous situation, in the high scenario, the least cost solution is when the petrol refined cost US$0.4 per barrel above the international price. In this case, on the one hand it is worthless expanding steps one and two of refining capacity, which correspond to modernization of two cracking units (Graph 5). On the other hand, it will not be necessary to invest more in pipeline capacity.

It can be observed that the most capital-intensive solution for the three scenarios happens where only the expansion of the refining capacity is justified.

6. CONCLUSIONS AND RECOMMENDATIONS

According to the findings of this work it can be concluded that the Colombian government should elaborate a white paper to restructure Ecopetrol in its vision as a company, its relation with the state and the stability and promotion of its employees. Amongst the crucial aspects of Ecopetrol restructuring are the following points:

Administration

- The Ecopetrol CEO should be appointed for a fixed period of about five years, following the successful restructuring of the central bank, with the possibility of being re-elected an indefinite number of times. The CEO should be provided with autonomy and clear rules to avoid being manipulated by the executive power.
- There should be clear requirements for electing members of the Board of Directors and the CEO itself based on applicable professional experience and academic merits.

Labour liabilities

- The pension fund created to afford pension liabilities should be separated from Ecopetrol accountancy in order to make the opening of the company towards private capitalization and its globalization viable.

Vision

- Ecopetrol should focus on profits and the government should provide it with autonomy for selecting its most convenient business strategy. For instance, Ecopetrol should not be prohibited from integrating backward to petrochemical, if it were felt profitable to do so.
- Ecopetrol should be opened up to both international competition and foreign partnership in order to compete in the global market. This would involve improving its competitiveness, pursuing international standards of efficiency and using benchmarking targets for its planning and development.
- The government and Ecopetrol should separate their accountancy, thus, subsidies for middle distillates consumed by low income groups should be funded through the national budget and not charged to Ecopetrol. Similarly, the government must

commit to a policy of not withdrawing economic resources from Ecopetrol to finance independent projects.

After undertaking this first series of measures, the next step should be setting a legal and stable framework for the capitalization and opening of Ecopetrol.

Capitalization

- Ecopetrol should be listed in the stock exchange market both in the country and abroad initially offering a minority stake of its shares in the search for fresh capital, should reduce its political dependency and form strategic alliances to scale up its businesses and improve its efficiency.

Globalization

- Ecopetrol should undertake a transboundary view of the business, looking to create partnerships, joint ventures and strategic alliances with foreign companies in order to obtain technology, capital, and know how from other companies as well as improving profitability and sharing risks associated with its business.

The Refineries

- Ecopetrol should focus its efforts on taking advantage of the Barrancabermeja refinery geographic location and size to improves its efficiency up to benchmark standards.
- Because of the very difficult state of the Cartagena refinery with lower level of conversion than the Barrancabermeja refinery plus a difficult geographic position, in the north coast, which leave it extremly vulnerable to foreign competition. Ecopetrol should look for a joint venture or a strategic alliance with a partner to share risks and obtain economic resources for any expansion or modernization including integration backward to petrochemical projects.

LP Model

- From the LP model results, it can be said that given any scenario of demand, low, medium and high, petrol refining and importing will be needed over the next 11 years. Furthermore, deciding what is going to be more important depends on the one hand, on the level of protection the government reflects in the taxation of the importing costs. On the other hand, it would depend upon how successful is the Barrancabermeja refinery in improving its competitiveness in comparison the its benchmarks.

6.1. Overall critical discussion of the merits and drawbacks of the study

The LP model could be a very useful tool for planning if there is an interdisciplinary team providing constant feedback to the model in order to better represent the real world. It means improving the model with deeper financial, environmental and technical information. However, LP modelling will always provide indications but not accurate information because there are too many assumptions involved and at the same time it neglects many things that could eventually happened.

The LP model developed in this dissertation is very figurative and gives an interesting indication of how variables of the business interact with oneanother, but the numbers, specifically the boundaries between changes are very sharp unlike those of the real world. Furthermore, the model assesses static situations; it cannot be used to make dynamic appraisal involving changes within the period considered.

The real merit of the dissertation does not lie on the numerical analysis of the LP model, but in the way the issue of petrol supply in Colombia was analyzed considering a broad range of perspectives. In this way, looking at the economics, the international trends, the environment, the internal political and social situation, and the destiny a developing nation like Colombia should pursue. The merit is having a general outlook on the problem reaching a list of recommendations, stating clearly a ‘priority order’, which, define what and why one recommendation is more important than another.

That is exactly what policy-making is, it is expected that the contribution of this dissertation will be a tool for planning the future of petrol policy in Colombia by

proposing a list of actions sorted according to priority. In the end, this may or may not happen as stated here, but at least this is 'petrol' for the debate.

6.2. Topics requiring further study

There is not a single topic that does not require further study, however it is possible to mention the most important.

- In the LP model the financial aspect and the expansion functions can have alternatives, in real world they are not fixed as it was assumed in this dissertation, therefore, further studies should assess alternatives and not a fixed expansion chain of activities for both the importing pipeline and the Barrancabermeja refinery.

- The level the government should protect the Barrancabermeja refinery reflected in taxes of the importing costs involving internalising the externalities.

- Defining the optimum quality of petrol to be pursued by the Barrancabermeja refinery.

- Finding the best way of internalising the externalities of environmentally friendly fuels like compresed natural gas in a free market with petrol and diesel.

- Assessing the best way of hedging the internal petrol pricing against sharp international fluctuation which the current Colombian social and economic situation can cope with at that time.

- Finally, finding out the most appropriate way to see these reforms through congress, how to persuade the Ecopetrol trade union and the Colombian people that the ablity to make changes in the present according to the world trends, will lead to a better quality of life in the future.

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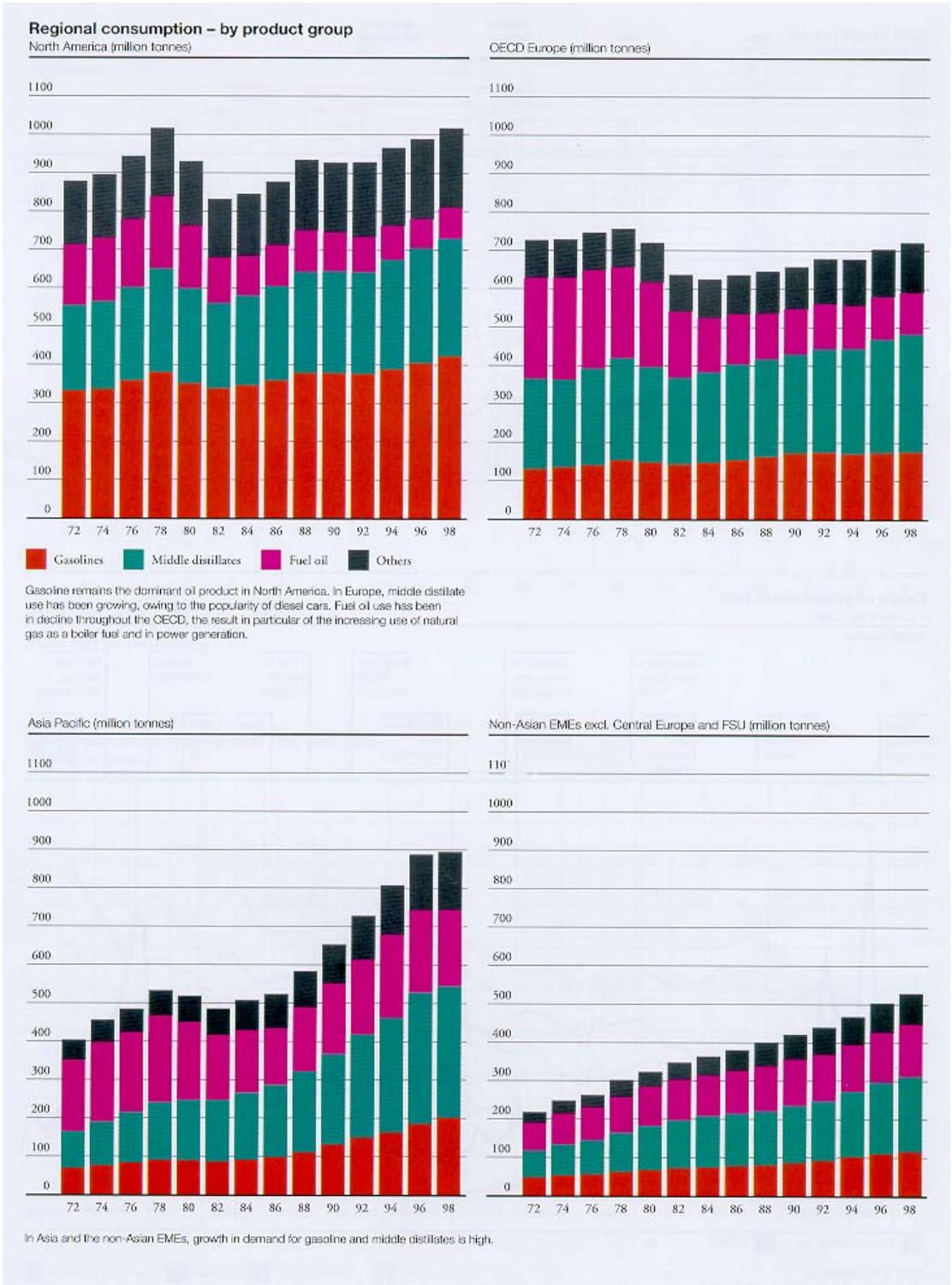
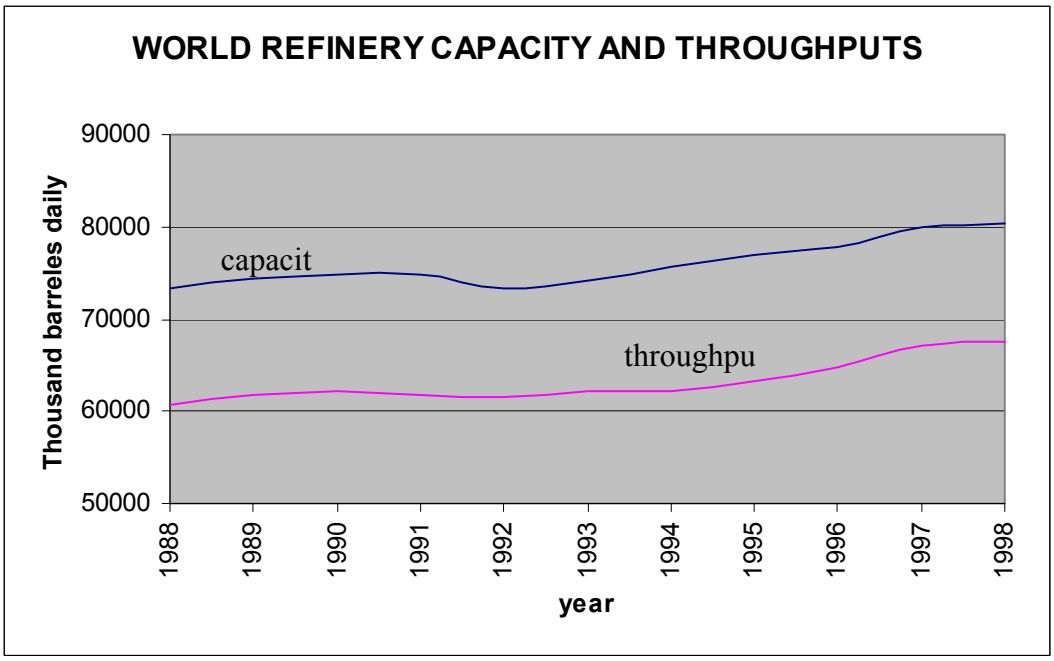
APPENDIX 1: WORLD FUEL CONSUMPTION BY REGION



Source: BP Amoco Statistical Review of World Energy 1999

Note: Gasoline consists of aviation and motor gasolines and light distillate feedstock.
Middle distillates consists of jet and heating kerosines, and gas and diesel oils.
Fuel oil includes marine bunkers.
Others consists of refinery gas, LPGs, solvents, petroleum coke, lubricants, bitumen, wax and refinery fuel and loss.

APPENDIX 2 REFINERY CAPACITIES AND THROUGHPUTS



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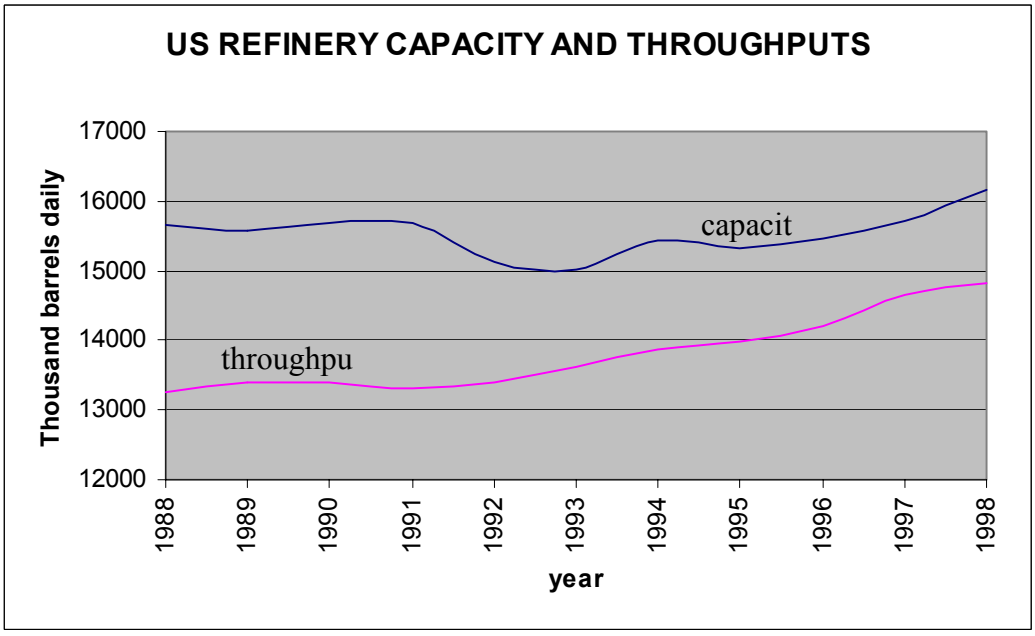

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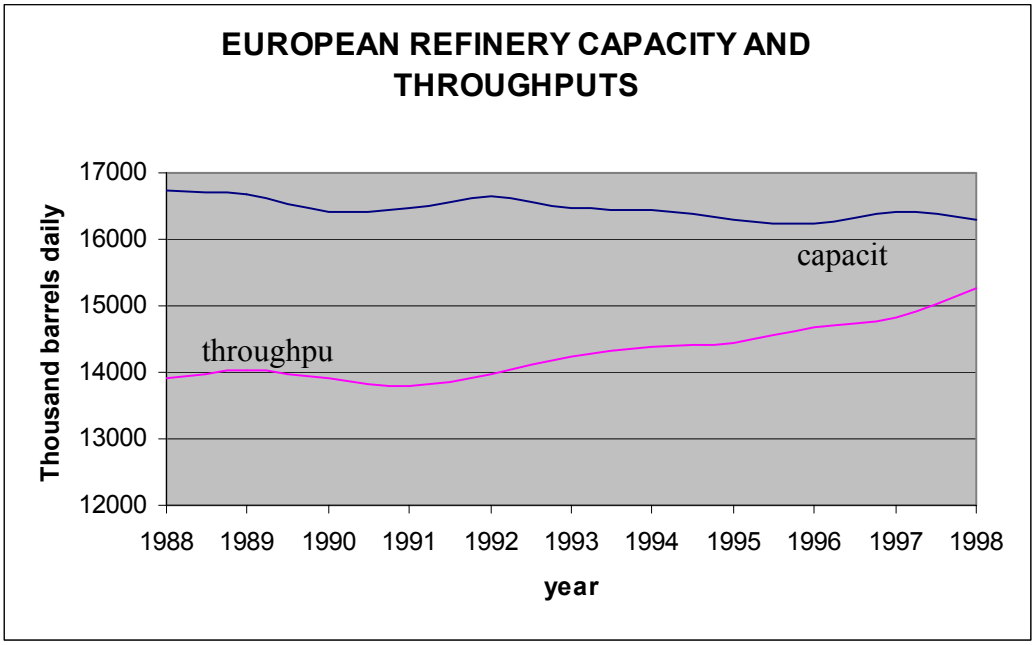

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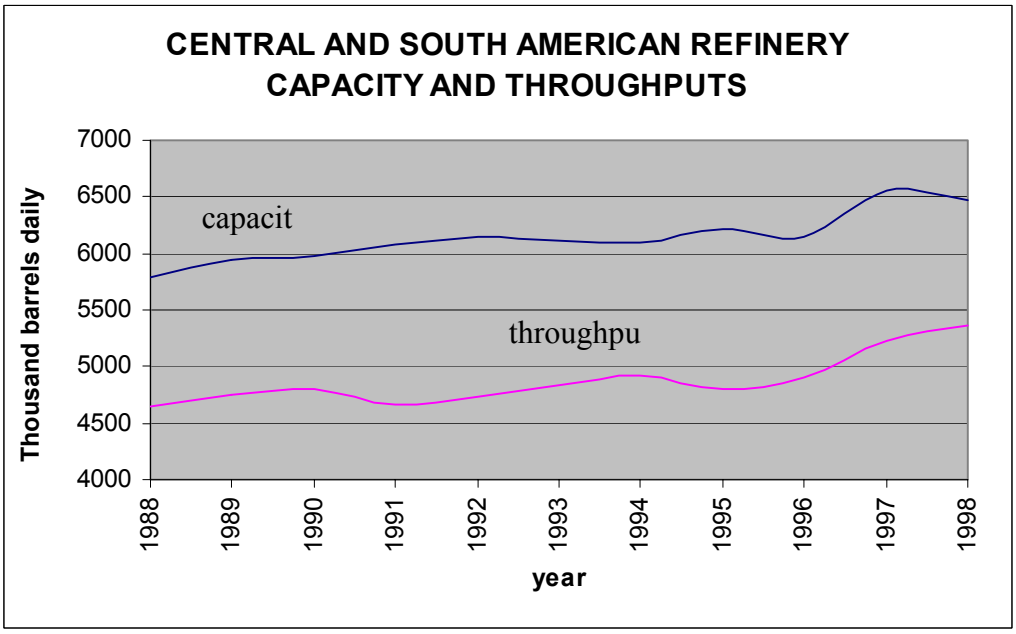
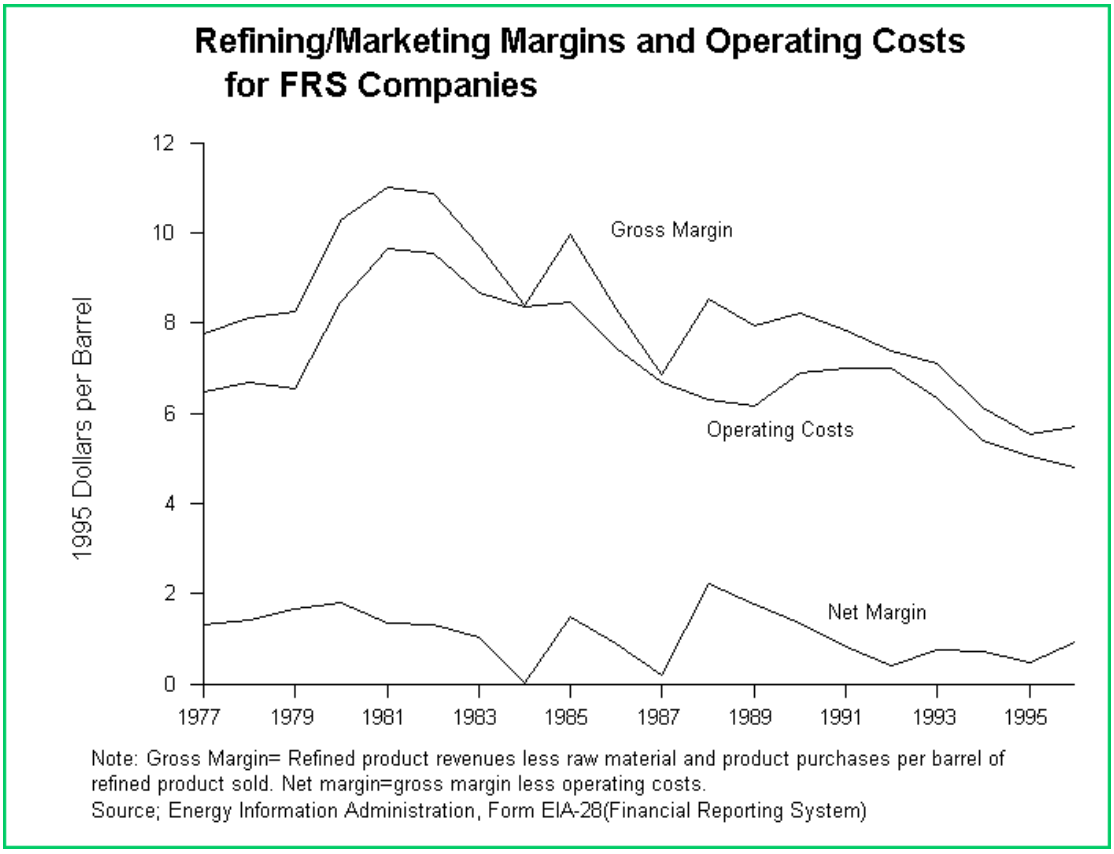
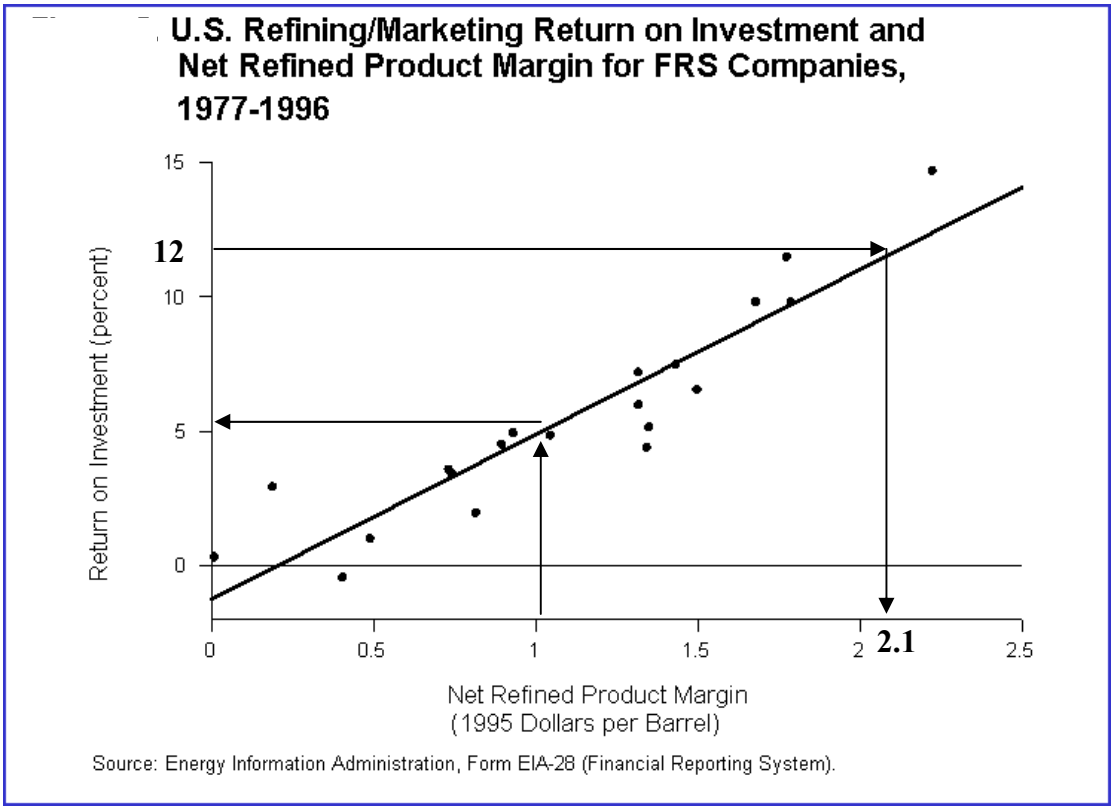


Source: BP Amoco Statistical Review of World Energy 1999

APPENDIX 3 REFINING MARGINS AND PROFITABILITY





APPENDIX 5 THE POZOS COLORADOS – GALAN PETROL IMPORTING PIPELINE

APPENDIX 6 COLOMBIAN OIL AND PETROL PIPELINE GRID 1999