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The Petrochemical Industry in Developing Asia

A Review of the Current Situation and Prospects for Development in the 1990s

Walter Vergara and Dominique Babelon

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Abstract

This report is a follow up of the global review of the petrochemical industry (The New Face of the World Petrochemical Sector: Implications for Developing Countries) published as Industry and Energy Series Technical Paper no. 84. The report's intent is to address the need for information on the petrochemical industry in Asia in view of the fast-evolving situation of the industry in the region and the growing involvement of the World Bank with operations and studies in a number of Asian countries. The document reviews the current trends of the industry with relevance for Asian-based producers and documents the substantial increases in activity and rates of growth of the sector in Asia. The current market situation in seven countries (Republic of Korea, India, China, Thailand, Malaysia and Indonesia) is also reviewed in some detail, including data on consumption, production and installed capacity for key petrochemical products and derivatives. The main issues in each country are summarized.

A substantial part of the analysis is dedicated to the assessment of competitive advantages in the production of petrochemicals by individual producers. The factors that help bring about comparative advantages are analyzed in some detail, using a simulation model of the economics of manufacture; by simulating specific operations, the report analyzes the different elements of competitiveness and asesses their impact in economic terms.

The study also reviews the policy framework in all countries selected and compares the different economic instruments and other policy tools that have been used to develop their industries. The last chapter includes a forecast of market development over the next 5 to 10 years; which estimates the demand/supply balances in the 1990s for major petrochemical products. A brief evaluation of the industrial strategies relevant to Asian-based producers is also developed. The report includes substantial data (statistical information) on markets, production capacities, production and demand and pricing for petrochemical feedstocks and products.

The report concludes that prospects for future development of the industry in developing Asia are generally favorable because of: a) the expanding domestic markets; b) the gradual evolution of the industrial policy framework toward a less restrictive environment, free trade and lesser protection; c) the opportunities for market integration and complementarity; and, d) the abundant gas resources in the region. As a caveat, the optimistic outlook hinges on the prospects for continuous economic growth and the oil supply and pricing situation. To secure their competitive position and materialize the growth prospects, countries with a lower competitive posture must move to improve their economics of manufacture through feedstock diversification, vertical integration, restructuring increased exposure to competition and improved long-term planning.

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The authors have also profited from valuable insight and comments provided by many colleagues at the World Bank and the International Finance Corporation.

Abbreviations and Acronyms

ABS	-	Acrylonitrile-butadiene styrene
ASTIF	-	Industry, Trade and Finance Division; Asia Technical Department; World Bank
BR	-	Butadiene rubbers
BTX	-	Benzene, toluene and xylene
DMT	-	Di-methyl terephthalate
EDC	-	Ethylene di-chloride
EG	-	Ethylene glycol
EPDM	-	Ethylene propylene diene monomer
EPR	-	Effective protection rate
FOB	-	Free on board
GATT	-	General Agreement on Tariffs and Trade
GDP	-	Gross domestic product
GOC	-	Government of China
GOI	-	Government of India
GOIN	-	Government of Indonesia
GOK	-	Government of Korea
GOM	-	Government of Malaysia
GOT	-	Government of Thailand
GNP	-	Gross national product
GSP	-	Generalized System of Preference
HDPE	-	High density polyethylene
IPCL	-	Indian Petrochemical Corporation Limited
IRR	-	Internal rate of return
KIET	-	Korean Institute for Engineering and Economic Studies
KPIA	-	Korean Petrochemical Industry Association
LDPE	-	Low-density polyethylene
LLDPE	-	Linear low-density polyethylene
LPG	-	Liquified petroleum gas
LNG	-	Liquified natural gas
MFA	-	Multifiber Agreement
MIDA	-	Malaysia Industrial Development Corporation
MtBE	-	Methyl t-butyl ether
MTY	-	Metric tons per year
NGL	-	Natural gas liquids
NIC	-	Newly industrialized country
NPC	-	National Petrochemical Corporation
NPV	-	Net present value
NR	-	Nitrile rubber
ONGC	-	Oil and Natural Gas Commission of India
PBR	-	Poly-butadiene rubber
PF	-	Polyester filament
PEF	-	Polyester fiber
PE	-	Polyethylene
PFY	-	Polyester filament yarn
PP	-	Polypropylene
PS	-	Polystyrene
PSF	-	Polyester staple fiber
PTT	-	Terephthalic acid
PTA	-	The Petroleum Authority of Thailand
PVC	-	Polyvinyl chloride

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Executive Summary

Introduction

The petrochemical sector plays an important part in the industrial strategies of developed countries. Its pivotal role in industrial modernization has been documented elsewhere (Jones, 1989; Fayad, 1986) and has been linked to progress in the manufacturing sector and the ability to promote exports (Stobaugh and Gagne, 1988). World sales of petrochemicals continue to increase and in 1988 reached US$385 billion equivalent, surpassing all other sectors of the chemical industry. With relatively low raw material prices, adequate feedstock supplies and high product prices, the general short-term outlook is for the industry to continue its strong performance and further penetrate diverse markets in the economy.

Although the industry in Asia is expected to continue growing at higher rates than in developed countries, the large number of parties involved, the investments considered, the cyclical nature of the industry and the globalization of the sector require that careful analysis be exercised in the development of options and strategies. This study reviews the current situation of the industry in Asia and, based on its historical performance and trends, analyzes its competitiveness against producers in the region and low cost producers outside of Asia and prepares likely future scenarios and strategies. The study is intended as background information and analysis on the status of the industry for decision makers and planners and as a guide for prospective Bank Group dialogue with countries in the region.

The specific purposes of the study are (a) to identify recent trends affecting the industry and assess their effect in the future development of the sector in Asia, (b) to describe the current situation in a sample of selected countries, including the policy framework and to forecast the demand and supply situation for key basic petrochemicals and derivatives, and (c) to assess the individual country and industry advantages for the production of petrochemicals.

Given the diversified nature of the industry and the many countries involved in petrochemical development in Asia, the study focuses on an indicative sample of 13 products and 6 countries. The products selected are representative of the industry. These include basic olefins, aromatics, major synthetic resins, rubbers and fibers. Together these products represent an estimated 60% of world sales of petrochemicals, and all major sectors of the industry. Some of the countries targeted in this study are an example of early and successful development (Korea) that could be used by newcomers, others were large producers or large markets undergoing an ambitious expansion program (China, India, Indonesia), while the remaining consist of successful industrializing economies entering or considering entry into the petrochemical market (Thailand, Malaysia).

Update of Global Petrochemical Trends

A review of long term trends for the industry was discussed in a recent report (Vergara and Brown, 1988).1/ For purposes of this study, an update of trends has been prepared focusing on the significant changes expected in the short term (1990s) that have the largest potential implications for Asia-based producers. These include the recent investment activities in olefins and aromatics, trends in environmental considerations and policy, changes in feedstock supply and international competition and an update on the regional consumption of petrochemicals.

Investment in the Sector. During 1988, the price difference between products and feedstocks to the industry increased considerably (see Annex 1). Although market prices have not yet reached levels comparable to those prevalent during the late 1970s and early 1980s, these increases have produced a significant rise in profitability all across the board for the industry. The increases in profits have resulted in record number of announcements for expansions and new units. In the US for example, since early 1988, 16 new ethylene crackers were announced with a total capacity of nearly 6.6 million tons (13% of worldwide installed capacity). The prospect of this volume of capacity entering into operation in the US in the next three to four years will undoubtedly shape the medium-term market conditions for olefins. A similar surge of new projects has been announced worldwide. In Asia alone, a total of 13 new crackers and expansions are now at various stages of construction and many others are under planning while several projects have been announced in the Middle East and Western Europe. A comparison of the expected 1995 demand with the projected capacity reveals that North America and the Middle East are likely to have surplus capacity while Asia and Latin America will remain net importers. North America is also likely to continue to be a price setter, given its large share of world production capacity and surplus situation.

The latest statistics available on key aromatics such as benzene and p-xylene, show that on a worldwide basis, operating capacities have remained at constant levels during the last years and still can comfortably meet global demands. Even though the long-term trend for demand of benzene and p-xylene shows high rates of growth, the situation continues to favor a slight surplus in the medium term.

Environmental Concerns. Worldwide, environmental concerns have moved to the front stage regarding future development of the industry. Although the industry has always been associated with environmentally sensitive issues, recent progress in emission performance is now well recognized. But, the steady improvements in point source emissions have been balanced by the issue of solid waste generation associated to the end products and the rising concern that manufacturers should share in the responsibility

1/ The New Face of the World Petrochemical Sector. World Bank Industry and Energy Series Paper No. 84. July 1988.

for managing the life cycle for all products, and accept liability for the generation of hazardous waste. For developing countries entering the market, the application of emission performance standards is eased by the accumulated experience of earlier entrants as well as the technology innovations introduced in the field. Still, the will and institutional capability to apply and enforce standards remains the most important element in environmental protection.

Feedstock Choice. The long term trends toward the use of lighter feedstocks in the synthesis of ethylene, typically ethane/propane, have been slowed down for at least the immediate future. There are two reasons for the change. First, naphtha prices following the large crude oil price reductions in 1986, were significantly reduced and have remained low. Second, the demand for polypropylene, which increased by 10% in 1987, increased again by 9% in 1988. Investors have seen the ample margins available to polypropylene and propylene and the flexibility in operation and higher propylene yield as added benefits to naphtha based production capacity, and this has resulted in a number of new projects planned to be based on naphtha and an increase in the ability of new producers to process a variety of feedstocks.

Increase International Competition. The large increases in production capacity in Asia coupled with the extensive potential domestic and regional markets in the region have put in evidence the role of countries located in that area in the global market for petrochemicals. A number of factors have contributed to this situation. These include widespread availability of technology at accessible costs, growth in the domestic markets of new and potential producers, and government support through the use of incentives and controls.

Market Share of Asian Producers. The recent developments in market evolution, investments and increased demand have contributed to increase the market share of Asian producers. Asia now accounts for 17% of all plastics produced, 15% of all rubbers and 34% of all fibers. The projections prepared in this study imply that growth will continue and will result in an even greater share of production by Asian producers in the world markets.

Review of Petrochemical Markets in Asia

The countries under analysis are at different stages of development. Korea has a mature industry with high per capita consumption, others like China and India are also large users but are behind in market development with a low per capita consumption, still others are just starting production to meet a growing domestic market and pursue export opportunities (Thailand, Indonesia), and Malaysia is a newcomer to the industry. This study includes the results of a country-by-country review of the petrochemical industries. The review includes an analysis of the historical trends, the feedstock situation, and an analysis of supply and demand for olefins, aromatics, resins, rubbers and fibers. Table 1 below summarizes the main indicators for market size, development and current activities for ethylene, the main basic petrochemical product, in the six countries, and Figure 1 illustrates the current situation in per capita consumption for some products. The current situation of the industry in the six countries, can be further summarized as follows:

- Korea — Advanced market, high per capita consumption, high growth rates, large exporter of end user products, ambitious expansion program, lacks domestic feedstocks.

- India — Lowest per capita user in the sample, large importer of intermediates and resins, moderate to high growth rates, large expansions under consideration, about to start use of gas, limited feedstock availability: gas is not in surplus and is expected to be a naphtha importer in the long term.

- China — Largest market in the area, but low per capita consumption. Largest importer of resins, high growth rate but growth is dependent on trade and currency restrictions and growth prospects are uncertain. Growing domestic shortage of refining feedstocks. Just finished an expansion program, considerable new capacity under consideration.

- Thailand — New producer, small but fast growing market, moderate per capita consumption. Limited feedstock availability, relatively expensive gas fractions.

- Malaysia — Yet to produce basic petrochemicals other than methanol, very modest domestic market, but moderate per capita consumption, large and inexpensive feedstock supplier, net long term exporter of gas and naphtha.

- Indonesia — Yet to be a producer of basic petrochemicals. Moderate size domestic market, low to moderate per capita consumption, long term exporter of naphtha and gas fractions.

<u>Assessment of the Countries' Competitive Positions in the Manufacture of Petrochemicals</u>

A comparative analysis of competitiveness in the manufacture of some petrochemicals was completed for all six countries. The factors that were reviewed to assess competitiveness included economic, commercial and technical advantages, all of which have an impact on the estimate of the economics of production of petrochemicals. However, competitiveness is mostly dependent on three major factors: (a) feedstock availability and price, (b) scale and capital costs, and (c) location in relation to markets. The results of the analysis show that the countries in the region are at various degrees of competitiveness in the production of petrochemicals (Table 2). Korea is most competitive in the production of downstream products where its advantages in capital costs, shorter implementation periods and higher productivities

Table 1: INDICATORS FOR MARKET SIZE, DEVELOPMENT AND CURRENT ACTIVITIES, 1988

	Ethylene domestic consumption			Ethylene capacity			Ethylene trade exports (imports)
	Total (mtpy)	Per capita (kg)	1988/ 1980 /b (%)	Oper- ation	Under constr. (mtpy)	Planned	('000 mtpy) /a
Korea	1,332	31.3	16.3	505	1,050	1,950	(732)
India	608	0.7	14.1	213	600	2,498	(416)
China	1,612	1.7	9.8	1,670	690	635	(862)
Thailand	195	4.0	14.0	0	315	250	(195)
Malaysia	124	7.5	11.5	0	0	500	(124)
Indonesia	271/c	1.5	10.5	0	0	375	(271)

/a Implied trade through trade in derivatives plus direct imports.
/b Annual growth rate.
/c 1987.

Source: Staff estimates.

Table 2: COMPETITIVENESS ANALYSIS CONCLUSIONS

Country	Remarks
Korea	Competitive production of downstream chemicals in the domestic market. Expected to be self sufficient in the short term.
India	Gas based production of olefins and production of aromatics is competitive in its own market. High cost producer. Will continue to be net importer.
China	Naphtha based production competitive only for domestic production. High cost producer. Major net importer.
Thailand	Gas based production competitive in its own market. Potential competitive exporter of downstream products to the Asia region.
Malaysia	Good potential position as exporter to the Asia region both for olefins and aromatic derivatives but will face crowded export markets.
Indonesia	Potentially, competitive against US imports to its domestic market. Export competitiveness conditional on improvements in capital costs and integration.

compensate for relatively higher feedstock costs. This is one of the reasons why the industry quickly integrated and why the Korean producers have the most to gain from a strategy that maximizes value added.

Malaysia and Indonesia although not yet producers are estimated to be potentially among the lowest cost manufacturers for olefins and aromatic feedstocks in the region. Because of comparatively lower capital costs, resulting from lower installation costs and lower opportunity costs of capital Malaysia could be able to pass these savings to downstream products. Malaysia is a good potential location for the industry and is in a good potential position as exporter to the region. Timing, though, may have an important role in defining the country outlook. Thailand is estimated to be able to compete with low-cost producers within Asia in downstream products. Even though the industry is still at a very early stage, it has the makings for a competitive position in the region. Its competitive position is the result of efficient implementation, careful location, timing, and low capital costs. China and India are at the high cost range in the industry. In China the limited availability of feedstocks and the relatively long implementation periods make it a high cost producer of basic petrochemicals, but it can produce competitively for its domestic market. In India, the advantages provided by the use of gas allow for the production of basic olefins at moderate prices, but high capital costs and long gestation periods combine to increase the production costs of downstream products. Although local manufacturers can compete for the Indian domestic market, with the current cost structure it will be very difficult for Indian producers to compete in the export market.

The Pclicy Framework

In the past, governments had intervened in the establishment of their country's petrochemical industry and have initially sought to shield it from import competition. Today, however, the policy framework in the various countries varies significantly, although there is a general tendency towards liberalization. In some countries like India, the policy environment remains restrictive and protective, in others such as Korea, it is becoming very open to both domestic and import competition. Invariably, the policy framework reflects (a) the stage of development of the petrochemical industry, and (b) the export orientation of the economy. Government interventions have been prevalent in a number of areas: controls over the pricing and availability of feedstocks, tariff and licensing against competing imports, capacity licensing, structure and ownership of the industry, special investment incentives, and concessional financing.

Pricing and availability of feedstocks are generally determined by the authorities in charge of the energy and refining sectors. With respect to naphtha, price levels are set sometimes in line with international prices (Korea, Thailand, Malaysia), sometimes at levels which seek to guarantee minimum returns on domestic refineries (India, Korea prior to 1985) and tax revenues to the state (India). Availability of naphtha is sometimes constrained by priority allocations to competing uses (gasoline) when there is a lack of domestic refining capacity and/or import restrictions. With respect to gas feedstocks, only Thailand and India have been faced so far with the issue of pricing gas fractions used in industry. Both countries are working at formulas linking their prices to their opportunity value or cost.

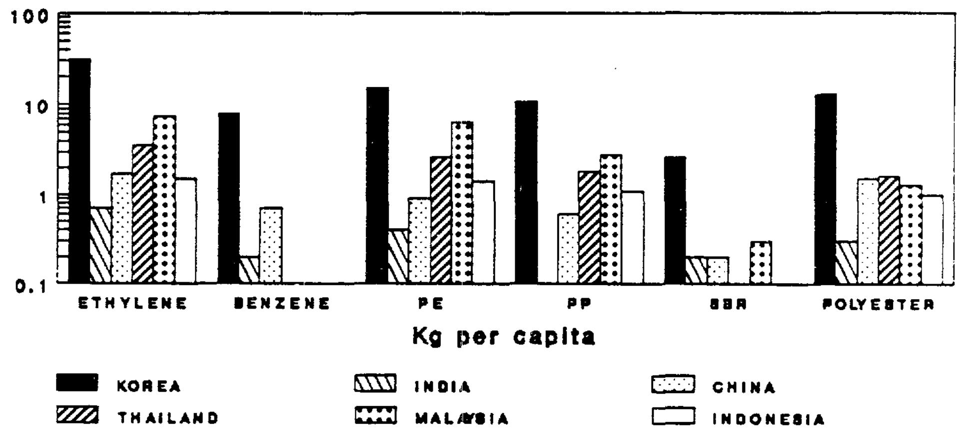
In the countries under study, governments have had a major role in shaping the ownership structure and integration of the industry through capacity licensing associated with a range of special investment incentives and concessionary financing. Licensing capacity, in particular, has been used to match supply to projected demand. Governments have often viewed public ownership, in particular of basic petrochemical plants, as necessary to complement private interest in downstream plants; to avoid concentration of ownership in the industry; or to avoid control by foreign investors. Capacity licensing policies have had some adverse effects (lack of integration, lack of domestic competition for market shares) which in only some countries are now being corrected through more liberal entry policies.

Trade protection policies (import licensing and tariff levels) and the subsequent degree of restriction to import competition they have introduced have had a major impact on the structure and efficiency of the industry. In this industry where economies of scale, choice of feedstock, location relative to feedstock sources and markets and capital costs are so important, there is evidence that high rates of nominal and effective protection (e.g., in India) have had adverse effects on industrial efficiency. Countries where a significant share of the industry's output is indirectly exported have been more careful to maintain or decrease protection levels to moderate or low levels (in particular Korea and Malaysia) in order not to penalize export-oriented downstream users. Several countries have also attempted to reduce the dispersion of tariffs between competing materials and along the vertical chain to avoid distortions in choice of materials and artificial biases in favor or against horizontal or vertical integration.

<u>The Outlook for Future Development</u>

The prospects for future development of the industry in the six countries are generally favorable. First of all, the domestic markets are expected to continue to grow and expand, soon converting Asia into a market of comparable size to other more developed regions. For example, the ethylene demand in the 6 countries is now more than 1.5 times the Japanese demand while just 10 years ago it accounted for only a small equivalent fraction. By 1995, demand for ethylene is expected to reach 10 mtpy as a result of a yearly growth of over 10% (Table 3). Plastics, fibers and rubbers are also poised to grow at similar rates. A second reason for optimism is the expected gradual evolution of the policy framework toward a less restrictive environment, freer trade and lesser protection. Although the countries in the sample are all across a wide spectrum of policies, the trends clearly point, with some exceptions, toward a less regulated industry better linked to market signals. A third reason is the differentiation of the markets in Asia that provide opportunities for mutual complementation. From the most sophisticated, highly integrated markets like Korea to those with clear advantages as suppliers of polyolefins (Malaysia), the region is a showcase of the stages of

Figure 1
PERCAPITA CONSUMPTION OF PETROCHEMICALS
(In Asia in 1988)



Source: Staff estimates

Table 3: PROJECTED DEMAND FOR PETROCHEMICALS IN ASIA, 1995
(million tpy)

	Developing Asia			
	Six countries	Others /a	Total	Japan
Ethylene	8.2	2.0	10.2	5.1
Propylene	4.7	1.3	6.0	3.8
Benzene	1.8	0.7	2.5	2.7
PE	5.6	1.3	6.9	2.9
PP	2.9	1.1	4.0	2.0
ABS	0.3	0.3	0.6	0.5
SBR	0.8	0.7	1.5	0.5
Polyester fiber	4.8	n.a.	n.a.	n.a.

n.a.: Not available.

/a Includes Singapore, the Philippines, Hong Kong and Taiwan.

market development in petrochemicals. The Asian producers have a lot to gain from this situation through complementary trade and markets.

Finally, the abundant gas resources in some countries in the region, in particular in Malaysia and Indonesia and the availability of other feedstocks, provide Asian producers with the possibility to become long term low cost producers of basic petrochemicals and a competitive manufacturer of downstream products. As a caveat, these generally favorable prospects hinge on the continuation of moderate growth on energy prices. Also, the outlook would be affected if additional large volumes of export oriented capacity were to be introduced by countries known to own vast resources of associated gas (such as Iran, Qatar, Algeria and others). To secure their competitive position and materialize the growth prospects other countries in the region with a lower competitive posture will benefit the most if actions to improve their economics of manufacture are taken now when prospects for progress of the industry in the region are favorable. Priority actions for Korea and Thailand relate to diversifying the feedstock base and continue vertical integration; for China and India restructuring in fibers and rubbers (India) is needed to improve competitiveness in those sectors; also in India the industry will benefit from (a) improving the efficiency of contractors and engineering companies to shorten implementation periods, and (b) increased exposure to competition through reduction in protection rates; for Malaysia and Indonesia, long term planning and access to export markets is required to develop its potential as low cost producers. Collectively, the industry must also address the issue of potential overcapacity through better communication, planning and discipline and the governments should intervene to apply and enforce emission performance standards to allow the industry to meet the challenges of increased environmental awareness.

I. INTRODUCTION

The petrochemical sector plays an important part in the industrial strategies of developed countries. Its pivotal role in industrial modernization has been documented elsewhere (Jones, 1989; Fayad, 1986) and linked to progress in the manufacturing sector and the ability to promote exports (Stobaugh and Gagne, 1988).

World annual sales of petrochemicals continue to increase at a fast rate and now total US$385 billion equivalent (Table 1.1) surpassing in sales and production all other sectors of the chemical industry. For example, world sales of olefins, plastics and synthetic rubbers increased 5%, 9% and 3%, respectively, in 1988 over the previous year. With relatively low raw material costs, adequate feedstock supplies and high product prices, the general short-term outlook is for the industry to continue its strong performance and further penetrate diverse markets in the economy. In Asia, the industry is the focus of large investments in infrastructure, production capacity and vertical integration and expansion (manufacture of end-user products) all of these in anticipation of further increases in demand for petrochemical products. Compared to other regions, Asia continues to lead in growth for all sectors of the industry (Figure 1.1).

Table 1.1: WORLD SALES OF THE CHEMICAL INDUSTRY BY REGION, 1988
(US$ billion)

	Total chemical sector	Petro-chemi-cals
Western Europe	285	125
US and Canada	240	100
Japan	165	70
Asia	40	27
Middle East and Africa	30	13
Latin America	15	7
Other	120	43
Total	895	385

Source: Jones, C., 1989, and staff estimates.

Although the industry in Asia is expected to continue growing at higher rates than in developed regions, the large number of parties involved, the investments considered, the cyclical nature of the industry and the globalization of the sector require that careful analysis be exercised in the development of options and strategies. This study is a follow-up of a previous report on the world situation of the industry which identified the Asia region as a high growth and fast evolving market for petrochemicals. The new study reviews the current situation of the industry in Asia and based on its historical performance and trends analyzes its competitiveness against producers in the region and low cost producers outside of Asia. The study is intended as background for decision makers and planners and as a guide for prospective Bank Group dialogue with the countries in the region.

The specific purposes of the study are:

(a) to identify recent trends affecting the global petrochemical industry and their effect in the future development of the sector in Asia (Chapter 2);

(b) to describe the current situation of the industry and its markets in a sample of selected countries, including the current policy framework, and to forecast the demand and supply situation for key basic chemicals and derivatives (Chapters 3 and 6 and Annex 2);

(c) to assess the individual country and industry advantages for the production of petrochemicals (Chapter 4); and

(d) to identify issues affecting future development of the industry (Chapter 6).

Given the diversified nature of the industry and the many countries involved in petrochemical development in Asia, the study focuses on an indicative sample. Therefore, 13 products and 6 countries were selected as targets of the study. The representative products are the three basic olefins: ethylene, propylene and butadiene, an aromatic (benzene), the five major commodity plastics (LDPE, HDPE, PP, PS and PVC) an engineering polymer (ABS), a synthetic rubber (SBR) and a synthetic fiber (polyester). Together these products represent an estimated 60% of world sales of petrochemicals, and all major sectors of the industry.

The countries targeted in this study were selected for a number of reasons. Korea is an example of early and fast development that could be used by newcomers, China, India and Indonesia are large producers or large markets undergoing ambitious expansion programs while Thailand and Malaysia consist of successful industrializing economies entering or considering entry into the petrochemical market. The sample provides the opportunity to look at the petrochemical industries at various stages of development, from highly developed (Korea) to virtually nonexistent (Malaysia) and its relation with markets also at different stages of maturity, from mature in South Korea to vastly underdeveloped (India, China). Finally, the countries selected follow a wide spectrum of industrial policies and therefore provide an opportunity to compare their effects on the petrochemical industry and the markets.

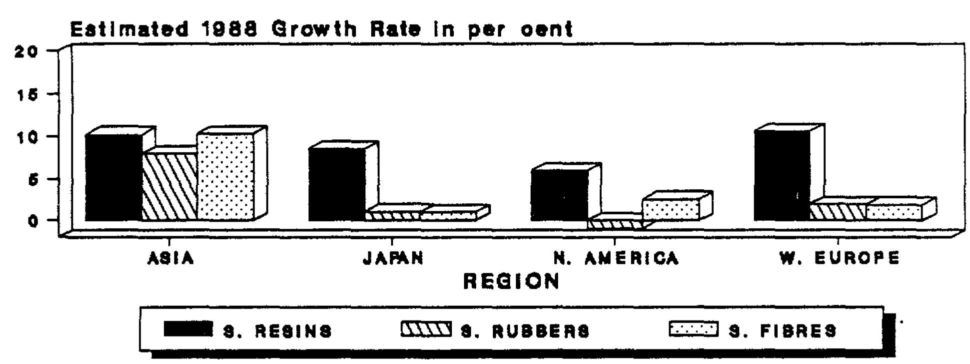
One element common to all these countries is the strong historical growth of the industrial sector. Additionally, South Korea, Thailand and Malaysia have been able to maintain export oriented economies and to successfully weather global economic cycles. The main economic indicators are summarized in Table 1.2 for all countries selected. The estimates and projections included in this report are always in economic terms, but only intended as a tool to enable a relative rating of the industry prospects in the countries under analysis. This caveat is particularly relevant for the price projections used to estimate future revenues for petrochemical industries, therefore the prices used and the results ought not to be seen in absolute but rather comparative terms.

Table 1.2: ECONOMIC PERFORMANCE INDICATORS OF THE SELECTED COUNTRIES

	GNP per capita (US$, 1987)	Annual inflation rate 1980-87	Annual growth rate of industrial output 1980-87	Gross domestic investment, annual growth rate 1980-87	Real growth of merchandise exports 1980-86
		(% p.a.)			
Korea	2,690	5.0	10.8	10.0	14.3
India	300	7.7	7.2	3.7	3.6
China	290	4.2	13.2	19.0	11.7
Thailand	250	2.8	5.9	3.9	10.2
Malaysia	1,810	1.1	5.8	-1.0	9.7
Indonesia	450	8.5	2.1	4.1	2.7

Source: World Development Report, 1989.

Figure 1.1
RECENT GROWTH PERFORMANCE OF THE PETROCHEMICAL INDUSTRY (BY SECTORS)



Source: Staff Estimates

II. GLOBAL TRENDS IN THE INDUSTRY

A review of long-term trends for the industry was discussed in a recent report (Vergara and Brown, 1988).1/ In that study, the recurring changes in the feedstock situation, the gradual saturation of the markets, the trend toward vertical integration of production and trends in trade, technology and new products were discussed. However, the petrochemical industry is cyclical in nature and strongly influenced by other sectors of economic activity, and therefore the driving forces shaping the market in a more immediate time frame must also be reviewed. For purposes of this study, an update of trends has been prepared focusing on the significant changes expected in the short term (1990s) that have the largest potential implications for Asia-based producers. The update covers the following aspects of the industry: (a) the investments flowing into olefins and olefins derivatives, its impact on the outlook for margins and prices, and implications for merchant ethylene producers; (b) the associated changes to the aromatics sector including the impact of new derivatives production capacity on the industry; (c) the trends in environmental considerations and environmental policy and its effect on the outlook of the industry; (d) a review of the feedstock supply and raw material situation in Asia; (e) the increased international competition in petrochemical manufacture and the relative position of Asian producers in the World Market (a detailed country by country analysis of competitiveness is included in Chapter 4); and (f) a review of the regional demand situation for the major sectors of the industry.

Investment in Ethylene and Derivatives

During 1988 and the first half of 1989, the difference between prices for products and the cost of raw materials to the industry increased considerably (see Annex 1). For ethylene, for example, the difference between the market price for ethylene and the cost of the required ethane for its manufacture was over US$500 per ton of ethylene for ethane based producers on the US Gulf Coast. This compares with the average US$240 per ton for the period 1985-87. A similar situation was experienced by naphtha based producers, with naphtha prices at low levels and ethylene and by-product olefins at relatively high prices. Commodity polymers, affected by limited supplies, experienced in various degrees large increases in prices, outpacing the increases in costs for olefins. Other basic chemicals and derivatives also experienced net increases in prices during the period 1986-88. Only synthetic fibers and basic aromatics failed to post similar increases in price. The recent price fluctuations for major petrochemical products are summarized in Figures 2.1 and 2.2. Although market prices have not yet reached levels comparable to those prevalent during the late 1970s and early 1980s, these increases coupled with relatively low and stagnant feedstock

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1/ World Bank, 1988. The New Face of the World Petrochemical Sector. Washington, D.C.

Figure 2.1
PRICE VARIATION OF BASIC PETROCHEMICALS AND FEEDSTOCKS

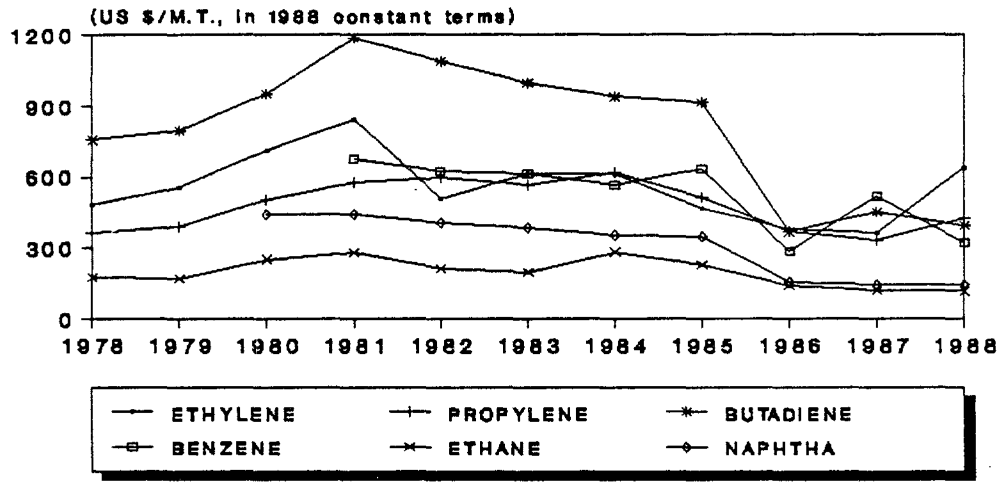
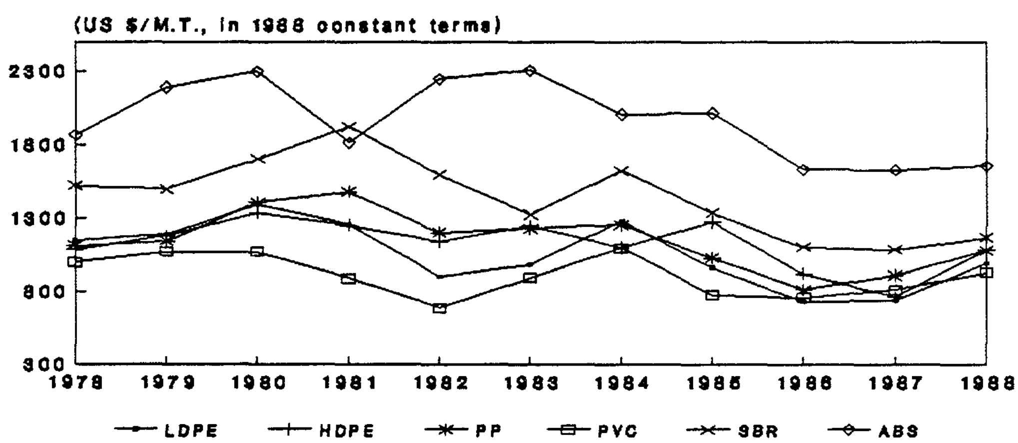


Figure 2.2
PRICE VARIATION OF KEY DERIVATIVES



prices have resulted in a significant rise in profitability across the board for the industry.

The increase in margins and consequently the higher level of revenues have attracted a number of potential investors and announcements for expansions and new units by established producers. In the US for example, from 1985 to the beginning of 1988, not one announcement for new cracking capacity was made, while during the period March 1988-mid 1989, 16 new crackers were announced with a total annual capacity of nearly 6.6 million tons (Table 2.1). This is equivalent to 13% of worldwide installed capacity (excluding Eastern Europe). Although it is doubtful that all the announced capacity will be built in the proposed timetable (some of the announcements may have been done to prevent new entries into the market), the prospect of a large new chunk of capacity entering into operation in the US in the next three to four years will undoubtedly shape the medium-term market conditions for olefins.

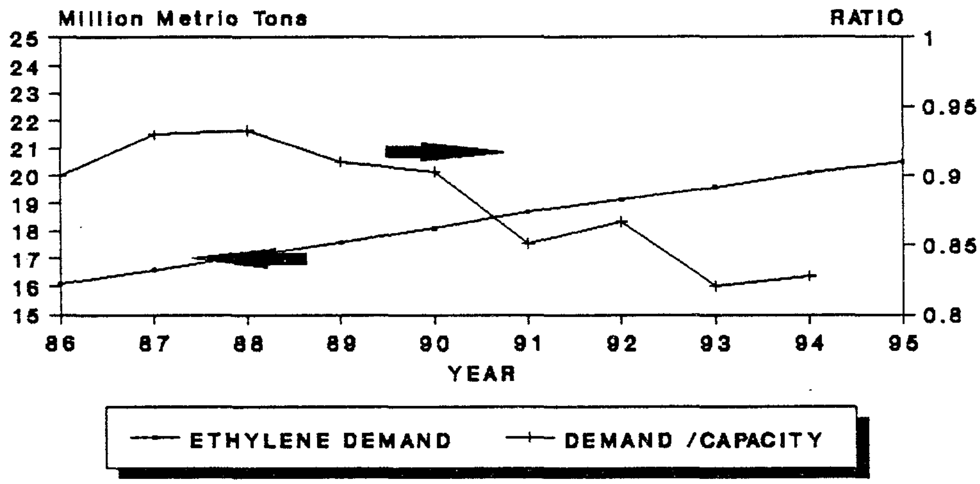
Table 2.1: ETHYLENE EXPANSION ANNOUNCEMENTS IN THE US (as of mid-1989)

Target start-up year	Capacity ('000 tpy)	No. of units
1989	765	4
1990	810	3
1991	1,750	3
1992	1,300	2
1993	650	1
1994	450	1
Other	900	2
Total	6,625	16

Source: Crouch, J., 1989 and staff estimates.

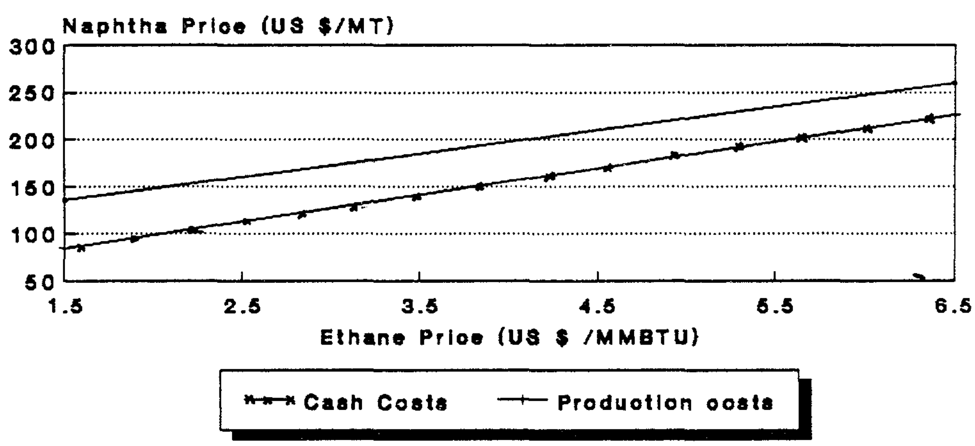
A similar surge of new projects has been announced worldwide. In Asia alone, a total of 13 new crackers and expansions adding up to 3 million tons of annual capacity of ethylene by 1995 are now at various stages of construction and many others are under planning (Table 2.2). Announcements for new ethylene capacity in the Middle East total 1.3 million tpy, in Latin America 2.0 million tpy and in Western Europe 1.5 million tpy. However, these announcements do not match in investment volumes or production capacities the large increases expected from the US and Asia. Overall, this flurry of activity raises the concern that the ratio of production to installed capacity is likely to fall in the next years as can be seen from a plot of announced

Figure 2.3
NORTH AMERICA. PROJECTED ETHYLENE DEMAND AND DEMAND TO CAPACITY RATIO



Demand projection based on 3.0-2.2%
gradually decreasing growth rate

Figure 2.4
SWITCHING FEEDSTOCK VALUES FOR ETHYLENE MANUFACTURE, 450000 TPY



(For US GULF COAST location
with Propylene at US $ 430/MT)
Prod. Costs include a 20% ROI

Table 2.2: DEVELOPING ASIA--NEW ETHYLENE CRACKERS UNDER CONSTRUCTION OR PLANNING

Country	Company	Size ('000 t)	Status	Feedstock	Schedule (year)
Korea	Daelim	300	C	naphtha	1989
	Yukong	400	C	naphtha	1989
	Lucky	350	C	naphtha	1992
	Samsung	350	P	naphtha	1995
	Hiunday	350	P	naphtha	1994
	Other (5)	1,300	P	naphtha	1996
India	IPCL	300	C	ethane/ propane	1989
	IPCL	100	P	ethane/ propane	1992
	Oswal	100	C		1990
	MRL	300	P	naphtha	1990
	Reliance	325	P	NGL	1994
China	Sinopec	300	C	naphtha	1990
		120	C	naphtha	1991
		130	C	naphtha	1990
		140	C	naphtha	1991
	Other (3)	900	P		1992-1995
Thailand	NPC	315	C	ethane/ propane	1994
		325	P	NGL/naphtha	1995
Indonesia	Shell/partners	315	P	pending	1994
Malaysia	?	300-400	P	ethane/ propane	?
Taiwan	China Petr.	400	C	naphtha	1992
	Formosa Pl.	400	P	naphtha	?
Total by 1995 under construction		2,855			
Total including planned units by 1995		5,820			

C: Under construction. P: Proposed.

Source: Staff estimates.

capacity additions against projected market growth for ethylene in North America (Figure 2.3).

Worldwide, ethylene demand has been projected to grow at an annual rate of 2.9% up to 1995, with developing regions growing at faster rates and Europe, Japan and North America at a much slower rate (World Bank, 1988). A comparison of the expected 1995 demand with the updated numbers for capacity under construction and planned confirms that N. America and the Middle East are likely to have surplus capacity by 1995. North America is also likely to continue being the price setter in the industry given its surplus situation and the large share of world production capacity. The data also show that the Asia region as a whole will easily absorb all new capacity under construction and still remain a net importer. If on the other hand all projects under planning materialize, Asia may significantly reduce its import dependence from other regions (Table 2.3). Nevertheless, many of the projects under planning in Asia are at a very preliminary stage and some are likely to be cancelled or postponed because of technical and market and environmental reasons. It is therefore likely that Asia will continue to be a net importing region through the 1990s.

Table 2.3: PROJECTED WORLD DEMAND AND SUPPLY SITUATION FOR ETHYLENE BY 1995

	Projected 1995 demand		Projected capacity in 1995		Ration of projected demand to projected supply /b (operation factor)	
	MMTY (A)	Annual growth rate 1995/1987 (%)	Current & under construction (B) --- (MMTY) ---	Current, in construction & planned (C)	(A/B) ---- (%) ---	(A/C)
North America	19.2	1.9	24.4 /a	24.4	78	78
W. Europe	14.7	1.4	15.5 /a	15.5	95	95
Japan	5.1	1.3	5.4	6.9	94	74
Asia	10.2	8.9	7.6	10.6	134	95
Latin America	5.6	6.8	4.0	5.1	140	109
Africa	1.5	12.4	0.6	1.1	250	136
Middle East	2.7	3.9	4.0 /a	4.0	67	67
Total	58.3		61.5	67.6	97	89

/a Includes all announcements.
/b A 95% ratio is the industry standard for full capacity in operation.

Source: World Bank, 1988, Vergara, W, 1989 and staff estimates. Eastern Europe not included in the estimates. Projected growth rates are considerably lower than historical rates. For details on the assumptions underlying the assumptions and scenarios considered see references above. Asia demand estimated based on country projections included in Chapter 6.

There are also other elements that may slow down the entry of new crackers into production. For one, the engineering and construction capability required to build a large number of plants is still limited after the effects of the last recession and now faces a large increase in orders worldwide. This workload is likely to result in long delays and extension of schedules. Second, contrary to the previous construction boom, where the oil companies had large cash excesses and were seeking positions in petrochemicals, this time the primary investors are chemical companies or consortia of downstream producers seeking to integrate. In other words, the driving force is not exogenous to the industry but rather the result of the reinvestment strategies of chemical companies necessarily concerned about the long-term viability of the industry and more cautious about the effects of overcapacity.2/

Impact on the Merchant Ethylene Market

The merchant ethylene market is estimated at less than 5.0 million tons worldwide (close to 10% of total production). But, with the trends in vertical integration and the expansion of basic chemical companies into downstream products, the base of the merchant ethylene market is expected to shrink in relation to total installed capacity. If ethylene capacity increases as expected, the first one to feel the effects in prices will be the merchant supplier. In addition, the expected increases in regional self reliance, and the costs of transportation should also work against merchant ethylene prospects. Although some specific areas will continue to offer merchant ethylene markets, the outlook for this type of operation is not likely to be attractive in the near future.

Update on the Global Aromatics Situation

The latest available statistics on key aromatics such as benzene and p-xylene, show that on a worldwide basis, operating capacities have remained at constant levels during the last years and still can comfortably meet global demands. In addition, growth in the demand for aromatics has been very affected by market saturation in industrialized countries where the key aromatic derivatives are used in mature applications such as housing, textiles and infrastructure development. Worldwide demand for synthetic fibers, the largest end user of p-xylene continues to lag behind the growth of olefins, plastics and rubbers. There are nevertheless a few points that need to be borne in mind when reviewing the aromatics market. First, the installed capacity of benzene derivatives is following the trend of expansions observed in the olefins/polyolefins markets. That is, a substantial number of expansions primarily in polystyrene/ethyl benzene are in the process of being implemented. Second, there is a gradual relative decrease in the availability of aromatic naphtha and this should decrease the effective production capacity of benzene. Both trends should contribute to tighten the worldwide supply of

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2/ If the global supply/demand projections and the resulting capacity utilization rates are correct, the situation in the mid 1990's won't be as critical as to what was experienced in 1984-1986.

benzene. In terms of p-xylene, the US continues to be the largest producer and consumer, accounting for over 5.7 million MT of capacity (32% of world total) and 4.6 million MT consumed. But, Asia remains the fastest growing producer of p-xylene and now has over 20% of the world production capacity with China alone accounting for 11% of the total. The continuation of the sluggish growth of the fiber sector in the developed countries combined with the active growth of the domestic markets in Asia is expected to result in a further concentration of production in the region and the continuing need for imports to the region (estimated at 0.4 million tons in 1988). In Asia, there is already a good number of aromatic projects already in construction or planning that will increase regional benzene capacity by one million tons and p-xylene capacity by 0.3 million tons. Even though the long-term trend for benzene and p-xylene derivatives shows continuing growth in Asia, the situation remains in favor of a worldwide surplus in the short term.

Environmental Concerns

Environmental concerns have moved to front stage regarding future development of the industry. Although the petrochemical industry has always been associated with environmentally sensitive issues, some progress in this area is now recognized. The widespread adoption of emission standards, the availability of new technologies that minimize effluents and maximize resource recovery and the realization by technology and engineering companies that environmental liability does not cease at plant start up even if local legislation is lacking or lax, has contributed to improve the record of the industry. But, the steady improvements in point source emissions have been offset by (a) the issue of solid waste generation associated with the end products, (b) the rising concern that manufacturers should share in the responsibility for managing the life cycle for all petrochemical products, and accept liability for the generation of hazardous waste, and (c) the realization that the long-term environmental effects of what were until very recently accepted industrial practices are associated with much higher social costs than was previously considered.

The issue of solid waste is evident in the concerns related to the degradability of plastics and its contribution to total solid waste, which have been apparent in recently proposed legislation banning the use of plastic products in some localities in the US and Western Europe and in the introduction of plastic and starch blends in the manufacture of films. Although the share of plastic products in total solid waste production in the US is below 7% of the total by weight, plastic residue is highly visible and the total volumes involved are considerable. Plastics are in particular vulnerable to criticism. According to a recent estimate, about 40% of total plastics production in the US, ends up in disposables. This would equal about 10 million tons per year, equivalent to the aggregated yearly production of plastics in the whole of Asia.

Recycling is one alternative to waste disposal, which has been used by other industries for a number of years, but presents practical complications when applied to plastics, since these products are subject to stringent specifications which make recycling unfeasible in many instances.

Another alternative is the use of recycled materials in new applications. Currently, very little plastic material is recycled in the US, (less than a fraction of 1% against 40% of all aluminum and 30% of all paper) but as pressure mounts to reduce the volumes of solid waste associated to plastics, recycling and reuse of plastic materials should increase. The introduction of recycled material even at modest levels will have an impact on the future of the industry by slowing down the rates of growth in consumption of commodity plastics and rubbers.

Incineration is another alternative to plastic disposal. Incineration not only reduces the large tonnage of solid waste (typically 1,000 tons yield 250 tons of ash) but can also generate electricity. There are nevertheless questions yet to be answered that cast doubts about the applicability of incineration to plastics. These have to do with the potential generation of dioxins and furans, the presence of heavy metals from plastic additives and the generation of acid gases from the incineration of PVC. There are also some concerns about the economic viability of incineration with energy prices at the current levels. Incineration is not likely to become a major disposal method for plastics in the short term.

Although a lot of attention is being given to solid waste generation from plastic disposal, the industry is also associated with liquid waste effluents and the emission of airborne pollutants. Comprehensive legislation to deal with these effluents has recently been enacted in the US and Japan. Application of emission and performance standards is nevertheless complicated by the large number of products involved and also by the continuous modification in processes design. Consider, for example, the recently completed source performance standards for the polymer industry in the US, which were released at the time when major innovations in reactor technology (slurry and tubular reactors) were entering commercial application. As a result, the standards are in some cases already not applicable or obsolete.

The main difference between air emissions from the petrochemical industry and other manufacturing processes is the heterogeneous nature of the emissions, mostly of hydrocarbon nature. Many of these compounds are toxic or hazardous and require special handling and disposal. Over the years, a number of techniques have been introduced to reduce hydrocarbon emissions at the source including floating roof tanks, vapor recovery lines, shipment of products by pipeline and others (Borup and Middlebrooks, 1987). These techniques have proven useful in the reduction of product loss and resource recovery while addressing pollution concerns. The cost of air pollution control systems varies widely with the process and control required. Because of the complexity of the air emissions it is not possible to summarize the efficacy and economics of control devices used by the industry. Recently built petrochemical plants have incorporated in most cases modern air pollution control systems. The problems are linked to the operation of old but economically viable units, designed before strict regulations were adopted. But, even today in developed countries the problem of fugitive emissions from petrochemical plants awaits comprehensive solutions. The installation of modern equipment for air pollution abatement in old or small scale plants may not be cost effective. In those cases where social and environmental benefits will result from efficient pollution control measures, economic incentives could be considered to assist in achieving compliance.

As in the case of air pollution, liquid effluents from the petrochemical industry are varied in nature. These include process and cooling waters, contaminated runoffs, product spills, ballast water, and start-ups and shut-downs liquid effluents.

The appropriate treatment for these effluents can only be optimized after a detailed review of the many operations that frequently are part of a petrochemical complex. Treatability studies are also being used to establish the operational parameters and removal efficiencies. All these require of resources and time for which allowance should be made at the feasibility stage. Biological treatment coupled with postfiltration has been defined by the US Environmental Protection Agency as the best practicable technology available for treating liquid effluents from petrochemical plants.

Attention has been given to the removal of toxic and hazardous materials from liquid effluents. These substances are not normally treatable through the biological and standard chemical treatments and often require the use of additional treatment operations such as carbon adsorption, wet air oxidation, steam stripping and others.

For developing countries entering the market, the application of emission performance standards is eased by the accumulated experience of earlier entrants as well as the technology innovations introduced in the field. Still, the will to apply and enforce today's strongest standards remains the most important element in environmental protection. Without enforcement, and or economic incentives, the improvements in legislation and enactment of standards will not result in pollution abatement and prevention.

Feedstock Choice

The long term trend toward the use of lighter feedstocks in the synthesis of ethylene, typically ethane/propane, has slowed down for at least the immediate future. The large increases in ethane based capacity have not materialized as quickly as was expected in the early 1980's. There are two reasons for this: First, naphtha prices following the large crude oil price reductions in 1986, were significantly reduced and have remained low. Therefore, today in many locations naphtha is competitive with gas feedstocks. In 1988, the average international market price for full range naphtha remained at US$155/MT, about half the price level of 1985 in constant terms. This reduction in prices increased the margins available to naphtha based ethylene manufacturers and has apparently been enough to gain some new production capacity. Second, the demand for polypropylene, which increased by 10% in 1987, increased again by 9% in 1988. This has caused a record number of additions to polypropylene capacity and therefore resulted in large requirements for propylene. Investors have seen the ample margins available in the manufacture of polypropylene and propylene and the flexibility in operation and higher propylene yield as added benefits to naphtha based production capacity. For example, in Asia, of all projects under construction, 65% of the total on a tonnage basis is expected to be naphtha based. The rapid changes in feedstock prices and availability has also resulted in an increase in the ability to process different feedstocks by new and established producers as a hedge against unforeseen feedstock variations. For example, some of the heavy feedstock crackers being proposed in the US are in fact wide range crackers capable to process many different feedstocks.

As shown in Chapter 4, ethane based producers with access to low-cost gas remain the most competitive and lowest priced among similarly sized plants. For naphtha to replace ethane/propane, in the synthesis of ethylene, in those countries naphtha prices would need to be further reduced. For a US Gulf location, current naphtha prices need to be lowered to $130 per MT and future prices accordingly for a potential investor to switch from ethane to naphtha purely on grounds of equivalent ethylene manufacturing costs, including return on investments (Figure 2.4). Yet, as illustrated by the large number of projects based on naphtha, other criteria such as by-product yields, flexibility of operation, and actual feedstock availability prevail.3/

The large volume of planned capacity being considered in Asia including many new proposals based on naphtha, raises questions about the availability of these feedstocks in the area. A recent Bank survey found that all the countries under study are likely to require additional refining capacity to meet the future demand for middle distillates and that given the expected domestic requirements for petrochemicals naphtha is likely to be in short supply in the area (Table 2.4). Also, naphtha is expected to keep increasing in price in proportion to projected increases in crude oil prices. Compared to other regions, Asia is therefore expected to face a tighter supply of heavy feedstocks and gradually step up the use of natural gas fractions depending on relative prices of gas and naphtha in each country.

Increase in International Competition

The additions to production capacity for petrochemicals in Asia coupled with the extensive potential domestic and regional markets in that region highlight the large share of Asian producers in the global market for petrochemicals. A number of factors have contributed to this situation. These are summarized below.

Technology Availability and Cost. Technology for many but the most specialized and advanced resins, rubbers and fibers is readily available in the world market. As an example, consider that over 50% of all synthetic fibers are now produced in countries other than Japan, the US and Western

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3/ The relative price of naphtha and ethane in the Middle East is not a significant determinant of new capacity in that region as the availability of ethane for petrochemicals is restricted as long as OPEC output remains at the current levels. All new announced capacity in Saudi Arabia will be based on naphtha.

Table 2.4: ASIA--EXPECTED DEFICITS OF MIDDLE DISTILLATES REFINING CAPACITY AND NAPHTHA SUPPLY BY 1995
(million bbl/year)

	Middle distillates	Naphtha
Korea	30	11
India	111	2
China	100	n.a.
Thailand	(65)/a	3
Malaysia	6	(2) /a
Indonesia	24	(2) /a

/a Figures in parentheses indicate surplus.
n.a.: Not available.

Source: Staff estimates.

Europe where the technologies were first developed. Developing Asia alone now accounts for 37% of all polyester produced. A significant fraction are exported as textiles to the countries where the processes were first developed. Because raw materials costs are roughly equivalent worldwide, and despite differences in capital costs, one key factor to compete with end products is the cost of labor involved in its manufacture. This is similar to the situation of rubber products, plastic parts and other end products where labor is an intensive input. The cost of technology and know-how for most of the basic and key derivatives is no longer an obstacle to new entrants. A new comer to the olefins business in some Asian locations can get a contractor to build a cracker and obtain costs that are comparable and some times lower than an established producer in Western Europe with millions of tons of installed capacity. (Shinnar and Buidan, 1988)

Domestic Markets. A large domestic market provides a major advantage by supporting the installation of full scale units without the need to rely on export of key intermediates and raw materials. The large potential markets in Asia (China, India, Indonesia) offer an opportunity for large scale producers that can competitively set up full scale units. If the market is actively growing as is the case of the relatively new markets in Asia, additional advantages in the form of continuous growth opportunities are available to local producers.

Government Support. Developing countries, and in particular those in Asia have moved forcefully to create and maintain their essential chemical industries. The governments's role has traditionally been to protect the industry during its early stages (Korea, Taiwan), to control production output (Korea, Japan, India) and to provide stimuli for establishment and growth

(Thailand, Malaysia). As market share and competitiveness increases, the role of the Government has generally decreased.

Market Share of Asian Producers

The data in Table 2.5 shows the impressive position already gained by the Asian markets as measured by current consumption. Asia now accounts for 17% of all plastics used, 15% of all rubbers and 34% of all fibers. The projections prepared in this study imply that the Asian markets will continue to grow although at lower rates and will result in an even greater share of production in the world markets during the 1990s (see Chapter 6).

Some of the large Asian based producers are expected to emerge in an even stronger position invigorated by a strong marketing position and possibly challenging the traditional megacompanies. Large producers in Korea like Kumho and Honam and public-sector companies like Sinopec (China) are already in a sales position comparable to large chemical companies in the industrialized countries. Others are expected to follow. The appearance for the first time of large chemical producers in the region introduces a new challenge to traditional producers. These large companies are expected to gain share in every segment of the industry, and slowly evolve into regional concerns through the establishment of production facilities in low cost countries in the region and of a network of producers and consumers throughout Asia. By gaining production volumes their links to the regional market will place them in a strategic place within the Asian market.

Another implication of the increase in market share and the reduction of tariff and nontariff barriers within Asia is an increased regional self-sufficiency for all subsectors of the industry. The emergence of new producers and evolution of the markets is expected to result in the Asian needs being increasingly met by Asian producers. There are simply enough raw materials, markets and investors to match.

The data in Table 2.5 also illustrate the level of world production of major groups of petrochemicals. The growth rates by sector are expected to continue a gradual reduction due to market penetration. For Asia, this study confirms the findings of the previous report and estimates annual growth per sector at comparatively higher rates than in any other regional market (Chapter 3 and Table 2.6).

Table 2.5: REGIONAL CONSUMPTION OF SYNTHETIC RESINS, RUBBERS AND FIBERS, 1988
(million MT)

	Synthetic resins /a		Synthetic rubbers /b		Synthetic fibers /c	
	Total	% of total	Total	% of total	Total	% of total
North America	17.8	31	2.5	23	3.0	23
Western Europe	16.6	29	1.9	17	2.6	19
Japan	6.3	12	0.9	8	1.3	10
Asia	9.7	17	1.5	15	4.8	34
Latin America	3.8	7	0.6	5	0.9	7
Other	1.5	3	3.5	32	0.9	7
Total	55.7		10.9		13.5	

/a Eastern Europe not included.
/b Includes SBR, BR, EPDM and NR.
/c Includes polyesters, polyamides and acrylic fibers.

Source: Staff estimates.

Table 2.6: OUTLOOK FOR GROWTH IN THE PETROCHEMICAL INDUSTRY BY SECTORS

	Consumption Growth rate 1980-87 (% p.a.)	World outlook	Asia's outlook
		(% p.a., 1988-95)	
Olefins	4	3	8-9
Resins	6	5-6	6-9
Fibers	3	2-3	5-6
Rubbers	3	2-3	3-4

Source: World Bank, 1988, and staff estimates.

III. REVIEW OF THE PETROCHEMICAL MARKETS IN ASIA

The countries covered by this study are at different stages of development. Korea has a mature industry with high per capita consumption, others, like China and India are relatively large producers but are well behind in market development (low per capita consumption), still others such as Thailand and Indonesia are just starting production to meet a growing domestic market and pursue export opportunities, while Malaysia is a relative newcomer in the industry. This section briefly summarizes the results of a country-by-country review of the petrochemical markets both for basic and downstream products.1/ The review of the historical growth of the domestic industries, including an analysis of the feedstock situation, and expansion plans is included as a country annex.

KOREA

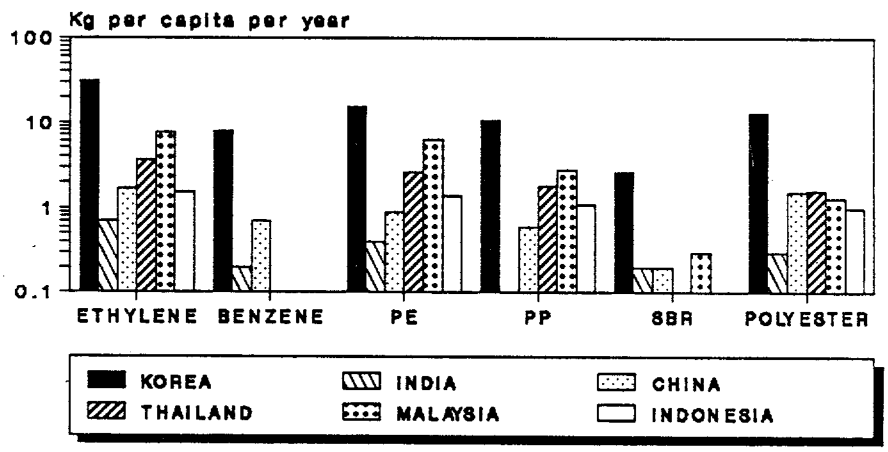
The current market for petrochemicals in Korea is characterized by the following factors: (a) very rapid growth in the consumption of derivatives, stimulated by the dynamic performance of the domestic economy and the successful tapping of export markets for end-user products, (b) the inability of the local producers to keep up with the growth in demand and the dependence on imported feedstocks, (c) the gradual phase-down of protection to domestic producers as markets and production developed, and (d) an increased competition from new and cheaper manufacturers in the Asia region. Domestic production capacity is summarized in Table 3.1

Basic Petrochemicals

The domestic requirements for basic petrochemicals have grown at high rates during the last 8 years. For example, the demand for ethylene during this period grew 16% annually and is now estimated at 1.3 million tons. The resulting per capita ethylene consumption (as well as for other olefins) places Korea on a class of its own together with Japan and Taiwan in the Asia region (Chapter 6) and at a much higher level than all other countries included in this study (Figure 3.1). The Korean market is also a major user of aromatics as raw materials for synthetic detergents, synthetic rubbers and fibers. Demand for benzene and toluene is growing at high rates (30% for benzene during the period 1986/1987) while the requirements for p-xylene have remained relatively constant as a result of the slow growth of the fiber sector. The domestic supply of benzene and toluene satisfies the demand but imports of p-xylene mostly from producers in Japan are required to meet the requirements for the production of synthetic fibers.

1/ The basic petrochemicals covered are olefins, benzene and methanol. Derivatives included are synthetic resins (plastics), synthetic fibers and synthetic rubbers.

Figure 3.1
PERCAPITA CONSUMPTION OF PETROCHEMICALS
(In Asia in 1988)



Source: Staff estimates

Table 3.1: KOREA--PRODUCTION CAPACITY
('000 mt)

Product	Installed	Under construction	Total
Ethylene	505	1,050	1,555
Propylene	268	521	789
Butadiene	94	247	341
Benzene	409	445	854
Methanol	0	0	0
LDPE	292	380	672
HDPE	280	200	480
PP	660	310	970
PS	424	260	684
PVC	540	10	550
ABS	190	52	242
SBR	150	32	182
TPA	500	460	960

Source: Korean Petrochemical Industry Association (KPIA) (1989) and staff estimates

Downstream Products

During the period 1980-1988, the domestic demand for synthetic resins grew from 644,000 tons to over 2 million tons (Table 3.2) and now accounts for about half of the Korean petrochemical sales (estimated at US$2.8 billion in 1988). The domestic producers have not been able to keep up with this growth, in part because of shortages in raw materials but also because of limitations in production capacity. The large increases in domestic demand for resins are partly explained by the success of the domestic automobile industry, electronic/electrical sectors and other consumer durables in Korea and the performance of the export sector.

Table 3.2: KOREA--DEMAND FOR BASIC AND DOWNSTREAM PETROCHEMICALS ('000 mt)

Commodity	1980 Production	1980 Net imports /a	1980 Total	1988 Production /b	1988 Net imports /a	1988 Total	Annual growth rate (88/80) (%)	Per capita demand (kg)
Basic								
Ethylene	372	26	398	600	732	1,332	16.3	31.3
Propylene	205	130	335	347	503	850	12.3	20.0
Butadiene	57	61	118	94	47	141	2.3	3.3
Methanol	209	-114	95	0 /c	164	164	7.0	3.8
Benzene	103	20	123	337	-1	336	13.4	7.9
Resins								
LDPE	112	23	135	283	70	353	12.7	8.3
HDPE	98	-28	70	263	42	305	20.1	7.2
PP	146	1	147	499	-44	455	15.1	10.7
PVC	237	-59	178	446	-25	421	11.3	9.9
PS	47	-4	43	328	-29	299	27.7	7.0
Engineering								
ABS	13	4	17	156	-32	124	28.0	2.9
Rubbers								
SBR	70	10	80	101	11	112	4.2	2.6
Fibers								
PF	137	0	137	328	42	370	12.8	7.5
PSF	140	0	140	306	-72	234	7.6	5.5

/a Direct and indirect through the import of derivatives.
/b Based on production records for first nine months of 1988.
/c Methanol manufacturing capacity was closed in 1985.

Source: KPIA, 1988, Korean Institute for Engineering and Economic Studies (KIET) 1988, and staff estimates.

Korea is one of the highest per capita users of synthetic fibers in the region. The efficient and competitive supply of synthetic fibers is critical to the growth of the domestic textile industry. But, Korea is not self sufficient in the production of raw materials for synthetic fibers: in 1987 for example, close to 70% of the 1.3 million tons of raw materials required by synthetic fiber producers were imported. The main reason for the shortfalls is the vigorous growth of textile and garment exports during the 1980's that quickly outpaced the domestic production capacity for raw materials. The future growth of synthetic fibers in Korea is threatened by a combination of factors: (a) the rising protectionism in traditional importer markets of Korean textiles, as illustrated by the phasing down of preferential status in the US; (b) the increases in the cost of the Korean labor force and the appreciation of the won; and (c) the increase in production capacity in other developing countries in the area (such as India and Malaysia) where manufacturing costs are considerably lower. Also, the Korean textile producers have significantly increased production capacity overseas and some of the traditional exports are now likely to be routed through the offshore plants while the local suppliers will probably concentrate on higher quality goods.

Compared to resins and fibers, production of synthetic rubbers has grown at a slower rate during the last 8 years (Table 3.2). Demand rose from 140,000 tons to over 200,000 tons during this period. The major stimuli for the market is the exceptional performance of the automobile and footwear sectors. Down the road, the sector is bound to face increased competition from cheaper producers in the area, more so if natural rubber producers diversify into synthetic materials and combine the advantages and flexibility of both sources.

Exports

It is difficult to estimate the fraction of petrochemical derivatives that ends up in exports. According to an estimate made by KPIA, about 25% of all plastics, 85% of fibers and 70% of synthetic rubbers end up in exported products. This trend is susceptible to change as a result of changes in the pattern of trade between Korea and industrialized economies. For example, the recent loss of status under the Generalized System of Preference (GSP), with the US, means that in the short term, Korean manufactured products will lose some of its competitive edge to other exporters from the region. This and the continuous revaluation of the won will exert downward pressure on Korea's ability to export.

Ownership and Integration

Ownership of the existing petrochemical complexes is in the hands of the private sector. Because of the integration of the industry the bulk of production is in the hands of just a few groups. This has also promoted early adoption of economies of scale. The industry is in the process of achieving a remarkable standard of vertical integration. By 1990, no olefin producer will be in the merchant market but serving captive demands. The existing conglomerates and the newcomers are all exploring expansion possibilities in terms of integration. This will further enhance the ability of the industry to compete in the international market.

INDIA

The market in India is characterized by the following factors: (a) chronic shortages in building blocks (ethylene, propylene) and downstream products which have slowed down market development; (b) a relatively high import resistance resulting from high protection rates and import restrictions; (c) very low per capita demand and high recycling rates resulting from the high costs of petrochemicals relative to the per capita income of the country; (d) high production costs, in turn a result of high capital costs and small scale of production.

Basic Petrochemicals

The domestic sector requirements for olefins have grown at a rate of over 14% over the period 1980-88, largely driven by the large increases in the market for synthetic resins (Table 3.3). Even at the current rates of growth, per capita consumption of olefins is among the lowest in the world (0.7 kg for ethylene in 1988), and lowest among the countries included in the analysis. Although adjustments have to be made to account for the very low per capita income in the country, the fact remains that India is one of the potentially largest domestic markets for petrochemicals in Asia (Table 3.4). The current demand for benzene is largely met through the installed capacity, but some imports are required to complement production of p-xylene.

Downstream Products

During the last eight years, Indian consumption of commodity polymers (LLDPE, LDPE, HDPE, PP, PVC and PS) has more than doubled. It grew from 267,000 tons in 1980/81 to 615,000 tons in 1988/89, an 11% p.a. growth rate. During this period, annual imports increased at a 16% annual rate to 287,000 tons, pushing India's import dependence from 37% to 52%. This impressive growth was achieved in spite of the very high domestic prices of plastics and reflects the early growth phase for consumption of these materials in India. Despite the rapid increases in consumption, per capita use of polyolefins remains among the lowest in the world (about 0.8 kg).

The textile industry is one of the largest manufacturing sectors providing employment to close to 20% of the labor force. The industry is largely based on natural fibers (cotton and cellulosics) and has only recently turned attention toward the potential for synthetic fibers. Despite the large share of manufacturing output by the textile sector (it accounted for 9% of manufacturing GDP in 1988), the per capita use of all fibers remains relatively low even by other Asian countries' standards.

Table 3.3: INDIA--PETROCHEMICAL PRODUCTION CAPACITY, 1989
('000 tons)

	Installed capacity	Under construction	Total
Ethylene	213	600	813
Propylene	96	133	229
Butadiene	24	14	38
LDPE /a	128	210	338
HDPE	50	115	165
PP	30	91	121
PVC	157	100	257
PS	22	-	22
ABS	7	5	12
Nylon-6	6	-	6
Polystyrene staple fiber	87	62	149
SBR	33	-	33
PBR	20	20	40
O-Xylene	27	61	88
Benzene	235	187	422

/a Includes LLDPE

Source: Government of India, Ministry of Industry, Department of Chemicals and Petrochemicals, and staff estimates.

The synthetic fiber sector still faces the issues of very high prices due to high tariffs and excise taxes, protection rates, excess capacity, in particular for polyesters, high costs of raw materials, small sizes for production units and low capacity utilization. As a result, the industry appears to be generally noncompetitive. Only recently have some steps been taken to upgrade the production capacity of fiber intermediates (xylene, PTA) through the commissioning of large-scale plants but the downstream sector still relies on a large number of small-scale units. Future market prospects will depend to a large extent on the ability of the industry to restructure and become competitive.

Most of the rubber consumed in India is natural rubber. As with synthetic fibers, the synthetic rubber sector faces high rates of protection, small sizes of production, and stiff competition from natural rubber. The future demand of synthetic rubber in India is expected to grow at a relatively high rate as a result of the increased demand by the transportation sector.

Table 3.4: INDIA--DEMAND FOR BASIC AND DOWNSTREAM PETROCHEMICALS ('000 mt)

Commodity	1980 Production	1980 Net imports /a	1980 Total	1988 Production	1988 Net imports /a	1988 Total	Annual growth rate (88/80) (%)	Per capita demand (kg)
Ethylene	155	56	211	192	416	608	14.1	0.7
Propylene	61	2	63	110	69	179	14.0	0.2
Methanol	44	12	56	45 /b	n.a.	n.a.	n.a.	n.a.
Benzene	64	1	65	126 /b	62	188	14.2	0.2
Commodity resins								
LDPE	71	3	74	81	64	145	8.8	0.2
HDPE	25	38	63	40	100	140	10.5	0.2
PP	13	2	15	38	27	65	20.0	0.1
PVC	50	32	82	130	110	240	13.1	0.3
PS	12	0	12	22	23	45	17.5	<0.1
Engineering								
ABS	1	0	1	4 /c	0	4	16.2	<0.1
Rubbers								
SBR	20	5	25	16	10	26 /a	n.a.	<0.2
Fibers								
PF	9	0	9	140	5	145	41.5	0.2
PSF	23	0	23	90	4	94	19.2	0.1

n.a.: Not available.

/a Includes the implied demand through the import of derivatives.
/b For 1986.
/c Estimate.

Source: Indian Petrochemical Corporation Limited (IPCL) and staff estimates.

Export Market

India is a net importer of petrochemicals and has no tradition in the export market. Some plastic products and synthetic fibers are exported but the volumes involved are very small. The high costs of local production and dependence on expensive feedstocks have prevented Indian manufacturers from entering into the international markets, despite the advantages in labor costs.

Ownership and Integration

At present, the Government encourages both private- and public-sector ownership in all phases of petrochemical manufacture. So far, however, the public sector is the leader in the production of olefins and synthetic resins and is expected to continue to play a prominent role. In other subsectors such as synthetic fibers, rubbers and detergents, private-sector participation is much higher than in the synthetic resins sector. As much as 70% of the aggregated production of fibers, rubbers and detergents is already in the hands of the private sector. The industry has integrated from the start, initially through the monopoly of the public sector (IPCL owned basic and downstream product plants), and small scale private producers but lately through an integrated approach to ownership and licensing approvals.

CHINA

The Chinese petrochemical industry was started in 1958 with the set up of the Gaoquiao Chemical factory in Shanghai and the subsequent construction of small scale ethylene crackers. The China National Petrochemical Corporation (Sinopec) was established in 1983 as a ministerial level corporation to consolidate petroleum refining and petrochemical processing. At the time of its formation, 39 of China's largest petrochemical enterprises and plants, previously handled by several different ministries, were placed under its jurisdiction. Sinopec now has about 600,000 employees, controls about 95% of China's petroleum refining capacity, 85% of ethylene production, 80% of synthetic fiber production, 75% of synthetic rubber and over 40% of plastics. Sinopec's plants are more advanced than those in the rest of China's chemical industry. The installed, in construction and planned capacities in the sector are summarized in Table 3.5.

The market situation in China is characterized by the following factors: (a) Growing imports of petrochemicals for the domestic markets notwithstanding the major efforts in expansion of local capacity. (China has become the largest importer of polymers in the region, with 1987 imports estimated at 1.3 million tons); (b) The emergence of a two tier pricing system under which output not covered under national or provincial plan allocations may be sold at "market" prices;2/ (c) Difficulties in securing foreign exchange to provide for the imports of equipment required for expansion of capacity and most recently for the imports of raw materials for the domestic sector; (d) Difficulties in logistics and distribution systems which makes internal trade expensive and unreliable, and (e) Outside of Sinopec, many small and widely scattered plants which hamper integration and increase production costs, relative to larger integrated units.

2/ In most cases there is control on upper prices levels, but prices do reflect much more accurately market conditions than the fixed prices that apply to allocated production. Whereas the fixed prices for allocated production are generally significantly below world prices, market prices are generally higher.

Table 3.5: CHINA--PRODUCTION CAPACITY, 1989
('000 MT)

Product	Installed	Under con- struction	Total
Ethylene	1,670	690	2,360
Propylene	606	n.a.	n.a.
Butadiene	507	n.a.	n.a.
Benzene	428	180	608
Methanol	629	0	629
LDPE & HDPE	855	315	1,170
PP	165	110	275
PS	31	73	104
PVC	606	0	606
ABS	23	30	53
SBR	201	80	281
PEF	615	107	722

Source: Sinopec, 1988; China Business Review, 1987; and staff estimates.

Basic Petrochemicals

The demand for olefins has increased at an annual rate of 11.1% during the period 1982-1987 to the current 2.8 million tons (see Table 3.6). This places China as the largest consumer of olefins in the region after Japan. Ethylene domestic demand is estimated at 1.6 million tpy out of which less than half was supplied through local production in 1987. Even to keep imports at their current volume, it is estimated that the Chinese industry would have to commission a world-size complex every three years. Likewise, benzene requirements have been increasing at an annual rate of 12% to a current (1987) requirement of 756,000 mty. The installed capacity is 610,000 mty. The balance is also supplied through imports.

Downstream Products

Following the pattern of other Asian countries, the Chinese plastic industry has been growing at a fast rate. For the period 1980-1987, the sector grew at an annual average rate of 15%. In 1987, last year for which statistics were available, total domestic consumption of commodity polymers is estimated at 2.4 million tons out of which 53 % or 1.3 million tons were imported. The imports of commodity polymers have grown by a factor of three during 1982-1988, converting China into the largest importer of plastics in Asia. The total cost of these imports in 1988 is estimated at US$2 billion.

Table 3.6: CHINA--DEMAND FOR BASIC AND DOWNSTREAM PETROCHEMICALS ('000 MT)

Commodity	1982 Production	1982 Net imports /a	1982 Total	1987 Production	1987 Net imports /a	1987 Total	Growth rate (87/82) (%)	Per capita demand (kg)
Basic								
Ethylene	565	443	1,008	750	862	1,612	9.8	1.7
Propylene	314	212	526	620	316	936	12.2	0.9
Butadiene	110	25	135	n.a.	n.a.	284	15.9	0.3
Benzene /b	383	50	433	493	263	756	11.7	0.7
Methanol	385	-46	339	454/c	156	610/c	17.0	0.6
Resins								
Polyethylene	313	421	734	515	699	1,214	10.6	1.2
Polypropylene	116	202	318	180	291	471	13.9	0.4
Polystyrene	2	63	65	36/c	164	200	25.2	0.2
PVC	424	16	440	579	84	663	8.5	0.6
Rubbers								
SBR	44	34	78	74/c	152	226	23.7	0.2
Fibers								
PF	14	78	92	80/c	531	611	46.0	0.6
PSF	207	116	323	680	296	976	18.7	0.9

/a Includes implied imports through imports of derivatives.
/b As a chemical feedstock only.
/c For 1986.

China is one of the largest producers and consumers (by tonnage) of synthetic fibers, ranking fourth in the world after the US, Japan and the Soviet Union. In 1987, China produced about 0.91 million tons of synthetic fibers, while total fiber production capacity by the end fo 1987 was estimated at 1.25 million tons which implies a 72% capacity utilization (Textile Organon, 1988). Even so, China continues to be a major importer of synthetic fibers. The reasons behind the low capacity utilization are varied but up to 1987 might have been related to the controlled low prices for some types of fibers which discouraged producers from increasing output (Ministry of Chemical Industry, China, 1988), and to the the small size of production unitsand relatively old facilities prone to suffer from maintenance and operation problems. The industry is not expected to be self-reliant in the near future and imports will continue even though at a lower level because of planned expansions of domestic capacity.

Total Chinese consumption of synthetic rubbers reached 300,000 tons in 1987. There are 9 synthetic rubber units in China, with a production capacity of 254,000 tpy. The rubber industry also relies on a large volume of natural rubber. The rubber industry is expected to grow rapidly in the short term because of the expected large increases in demand by the transportation sector and the phase-down of some natural rubber in tire applications.

Ownership and Integration

With the establishment of Sinopec in 1983, the GOC took an important decision regarding the pattern of ownership. Sinopec is now the largest producer in China and with the commissioning of the new crackers will surpass in sales large companies in industrial countries. The public sector through Sinopec and the provincial governments is expected to remain the dominant force in the industry with a small but increasing foreign private partnership. As a consequence of the patterns of ownership and the dominant role of Sinopec in planning, the new Chinese complexes are well integrated. For example, the new Beijing complex groups at one site under the management of Sinopec a total of 15 units sharing infrastructure and utilities. The same is true for the new plants at Quilu and Daquing.

THAILAND

The petrochemical sector is a newcomer in Thailand. In 1984, the Government resolved to set up a complex sized to meet the domestic demands for commodity polymers using natural gas fractions as feedstock. Commissioning is expected by the end of 1989. Upon completion the plant will consist of two main units: an ethane/propane cracker, and a propane dehydrogenator. With the operation of the first complex, Thailand will become an important producer of commodity polymers in the region with repercussions for local processors and manufacturers; still, the country will remain a net importer of styrenics and aromatic derived products. The GOT is in the process of examining, with IFC assistance, the viability of an aromatics and an olefins complex to be located next to a refinery and in the area of Ma tha Put, on the eastern seashore, respectively. The expected nominal capacities of the first and second cracker and aromatics plant are summarized in Table 3.7.

The market for petrochemicals in Thailand can be described as follows: (a) It consists of a medium-sized market experiencing a relatively high rate of growth; (b) It has received a great deal of foreign investment for the manufacture of end-user products, particularly through petrochemical companies located in Japan and Korea in search of a cheaper base for manufacture of raw materials for end use products; and (c) The private and public sectors have collectively organized to support the establishment of full-scale capacities.

Basic Petrochemicals

The demand for olefins in Thailand is summarized in Table 3.8. Out of the total ethylene demand, 150,000 tons or 76% of the total is represented

Table 3.7: THAILAND--NOMINAL CAPACITIES OF PETROCHEMICAL COMPLEXES ('000 mt)

	NPC-1 (actual)	Second complex (proposed)
Ethylene	315	250
Propylene	105	165
Butadiene	--	17
Benzene	--	121
LDPE	65	100
HDPE/LLDPE	197	--
PP	70	160
PVC	140	--
ABS		30
PTA		105

Source: Staff estimates.

by direct imports of ethylene. The annual growth rate is estimated at 14% during the period 1980-87.

Downstream Products

The domestic market for synthetic resins is still very new (i.e., comparatively low per capita consumption) and growing at high rates. The current demand is estimated at 370,000 mty which represents an annual growth rate of 13% during the period 1980-1987. At present, over 35% of total consumption is met through imports. There is an increased interest by Asian companies in Thailand as a base of operations for export oriented products. In 1987, investors from 20 countries put forward proposals for 1,161 mostly export-oriented projects in Thailand with a concentration on electrical appliances, electronics, auto parts. Export-oriented investments will have an impact on the domestic demand for synthetic resins, engineering plastics and other petrochemicals that go into the manufacture of end products.

The fibers industry is mostly based on natural fibers, with no domestic capacity for chemical intermediates for synthetic fiber production. The first PTA plant in Thailand is to be included under the downstream projects of the second petrochemical complex with an anticipated production capacity of 105,000 tons. The outlook for the textile industry continues to be bright as other countries in the region are phased out of special import tariff treatments and experience currency appreciation. An increase in the local availability of intermediates and fibers should contribute to an improvement in the competitive position of the industry.

Table 3.8: THAILAND--DEMAND FOR BASIC AND DOWNSTREAM PETROCHEMICALS ('000 MT)

Commodity	1980 Production	1980 Net imports /a	1980 Total	1987 Production	1987 Net imports /a	1987 Total	Growth rate (87/80) (%)	Per capita demand (kg)
Ethylene	0	89.5	89.5	0	195.4	195.4	13.9	3.6
Propylene	0	46.3	46.3	0	105.9	105.9	13.0	2.0
Butadiene	0	0.2	0.2	0	1.7	1.7	40.0	<0.1
Methanol	0	9.0	9.0	0	12.9	12.9	12.6	0.4
Benzene	0	0.6	0.6	0	4.5	4.5	30.7	0.1
Commodity Resins								
LDPE	0	35.4	35.4	65.0	-10.2	54.8	6.4	1.0
HDPE	0	31.4	31.4	60.0	29.5	89.5	16.1	1.6
PP	0	43.9	43.9	0	101.1	101.1	12.6	1.8
PVC	0	30.6	30.6	132.4	-38.4	94.0	17.3	0.7
PS	0	15.9	15.9	39.7	-8.3	31.4	10.2	0.6
Engineering								
ABS	0	0.8	0.8	2.0	1.1	3.1	22.0	<0.1
Rubbers								
SBR	n.a.	n.a.	3.7	n.a.	n.a.	5.9	6.8	0.1
Fibers								
PF	n.a.	n.a.	15.0	24.2	-2.3	21.9	4.6	0.4
PSF	69/b	n.a.	54.0	67.3	1.1	66.2	2.5	1.2

/a Includes implied imports through the imports of derivatives.
/b Total polyester.

Source: Ministry of Commerce and staff estimates.

MALAYSIA

Proposals for the establishment of a basic petrochemical complex in Malaysia can be traced back to the mid 1970s. But the uncertainties in the market of the time and the ensuing world economic recession dissuaded the GOM from endorsing the proposals. A new master plan for the petrochemical industry was prepared in 1985 and later adjusted to reflect the stage of progress in the availability and supply of natural gas and natural gas liquids. The industry is therefore facing a new developing stage, when a decision on an olefins complex will definitely shape the outlook for the domestic industry.

Basic Petrochemicals

Malaysia has no manufacturing facilities for basic petrochemicals, and a relatively limited domestic market, too small to justify world scale olefins or aromatics plants. The requirements for ethylene, for example, are estimated at 124,000 tons per year and have been growing at an annual rate of 11.5%. The only large basic chemical plant in operation is the export based methanol plant (domestic market for methanol is sized at 51,000 tons while annual production is 545,000 tons).

Downstream Products

There are four local producers of synthetic resins supplying about 25% of the total demand of the domestic market. The local production capacity is summarized in Table 3.22 below. the domestic market for commodity polymers has been growing at a composite rate of nearly 14% per year and imports have grown at even a faster rate despite the recent additions in capacity.

Malaysia is the world largest exporter of natural rubber and accounts for close to 7% of world production (Malaysian Business, 1988). The share of synthetic rubber in the domestic demand for rubber in Malaysia is relatively small (8% in 1986), but the Industrial Master Plan objectives for the rubber sector foresee an increase of domestic consumption of rubber to about 300,000 tpy by 1995 including 100,000 tpy of synthetic rubber while converting the country into a major tire and tube exporter.

INDONESIA

Despite the several attempts of the last 15 years, the abundant volume of gas and oil resources, the installed refining infrastructure and the strategic geographical location, the petrochemical industry has yet to establish its first olefins complex in Indonesia and has only very recently crystallized plans for the construction of an aromatics plant. The reasons for the continuous delays in the implementation of the industry are many: some of the failures can be attributed to the variations in the oil markets and its linkage with the financial health of Pertamina, part to the difficult balance of payments situation experienced during the 1980's and part to a lack of a clear long range development program for the industry.

Because of its privileged feedstock situation (Annex 3), the improvements in the economics of the sector has spurred anew the interest on Indonesia as a potential competitive producer and supplier for the merchant markets in the region. Additionally, the growth in domestic markets has already created a large enough base to justify world size plants to be located in the country. Therefore, a number of new and old proposals have again been brought to the table and some have gone beyond the planning stage. These include ambitious projects for the production of olefins, aromatics, synthetic resins, rubbers and specialty chemicals (Table 3.11).

Table 3.9: MALAYSIA--PRODUCTION CAPACITY, 1989
('000 mt)

	Installed	Under construction	Total
Ethylene	0	0	0
Propylene	8	80	88
Butadiene	0	40	40
Methanol	660	0	660
PP	0	80	80
PS	30	0	30
PVC	39	0	39
ABS	0	0	0
SBR	0	0	0
PF	41	0	41

Source: Malaysia Industrial Development Corporation (MIDA) and staff estimates.

Table 3.10: MALAYSIA--DEMAND FOR BASIC PETROCHEMICALS
('000 MT)

Commodity	1980 Production	1980 Net imports /a	1980 Total	1987 Production	1987 Net imports	1987 Total	Growth rate (87/80) (%)	Per capita demand (kg)
Ethylene	0	58	58	0	124	124	11.5	7.5
Propylene	0	25	25	0	50	50	10.5	3.0
Butadiene	0	3	3	0	2	2	-4.2	0.1
Methanol	0	14	14	545	-494	51	20.2	3.0
Commodity Resins								
Polyethylene	0	48	48	0	104	104	11.7	6.3
PP	0	24	24	0	47	47	10.3	2.8
PVC	0	10	10	39	2	41	21.9	2.5
PS	6	4	10	16	19	35	20.2	2.1
Rubbers								
SBR	0	4	4	0	5.4	5.4/b	negl.	0.3
Fibers								
PF	40/c	-12/c	28/c	43	-20	23	negl.	1.4

/a Implied imports through the imports of derivatives.
/b 1986.
/c 1984.

Source: Staff estimates.

Table 3.11: INDONESIA--PRODUCTION CAPACITY, 1989

	Installed	Under construction	Total
Methanol	330	--	330
Benzene	--	120	120
PP	10	--	10
PS	41	P	P
PVC	94	14	108
ABS	0	4	4
SBR	0	25	25
PTA	150	75	225
PFY	89	29	108
PSF	83	37	120

Source: Ministry of Industry, 1989, and staff estimates.

Basic Petrochemicals

Indonesia has no domestic production of olefins. The domestic producers of ethylene derivatives are supplied through imports of the key intermediates (styrene monomer and VCM) and the domestic market of polyolefins is mostly met through imports of the polymer or the end user products. There is no terminal for the import and handling of ethylene. The implied ethylene demand has grown at an annual rate of 10.5% and is now estimated at 271,000 tpy. The volume of domestic requirements already justifies, in terms of size, the set up of an ethylene cracker. The market for aromatics is tied to the requirements of the synthetic fiber industry. Polyester staple fiber and polyester filament yarn are the most widely used aromatic derivatives. The aromatics sector will greatly benefit from the planned capacity for benzene and paraxylene. Indonesia is also a large methanol producer.

Downstream Products

The domestic production capacity of synthetic resins is summarized on Table 3.12. The local market is smaller compared to Korea and China but constitutes the second largest importer of polyolefins in Asia (after China) which makes even more striking the fact that very little domestic production capacity has developed over the years. The domestic demand has grown from 350,000 tpy in 1980 to 556,000 tpy in 1987 for an equivalent 7.8% annual growth rate.

The rubber industry is dominated by natural rubber. Indonesian production of natural rubber is estimated at 1.1 million tons and accounts for 26% of world exports. Indonesia also imports about 22,000 tons of synthetic rubber. The GOIN is mindful of the need to improve quality and increase exports of rubber products (now only 2% of total rubber exports by value). It is therefore promoting the expansion of rubber processing capacity and installing synthetic rubber plants.

Table 3.12: INDONESIA--DEMAND FOR BASIC AND DOWNSTREAM PETROCHEMICALS ('000 MT)

Commodity	1981 Production	1981 Net imports /a	1981 Total	1987 Production	1987 Net imports /a	1987 Total	Annual growth rate (87/81) (%)	Per capita demand (kg)
Basic								
Ethylene	0	149	149	0	271	271	10.5	1.5
Propylene	0	131	131	0	203	203	7.5	1.2
Butadiene	0	1	1	0	10	10	41.6	0.1
Methanol	0	30	30	184	94	278	45.2	1.6
Benzene	0	15	15	0	22	22	5.6	0.1
Commodity Resins								
Polyethylene	0	136	136	0	246	246	10.4	1.4
PP	0	126	126	2	192	194	7.5	1.1
PVC	51	23	74	83	9	92	3.7	0.5
Engineering								
ABS	0	1	1	2	0	2	9.0	<0.1
Rubbers								
SBR	0	2	2	0	13	13	41.6	0.1
Fibers								
PF	0	1	1	85	0	85	97.9	0.5
PSF	0	1	1	81	0	81	122.8	0.5

/a Includes the implied demand through the import of derivatives.

Source: Staff estimates.

The Current Market Situation in Japan

A brief summary of the current market situation in Japan has been prepared to update the information covered in detail by a previous study (World Bank, 1988) and provide a basis of comparison with the countries under study. The situation for the sector in Japan can be broadly characterized as follows: (a) the industry plays a very important role in the national economy, representing a total output of over US$42 billion, and is a major producer of basic petrochemicals and derivatives, accounting for over 12.5% of world production of olefins, 12% of all synthetic resins and 18% of all synthetic fibers (the historical and current consumption data for key petrochemicals are summarized in Table 3.13); (b) the market is mature and slow growing, with an elasticity of demand of basic petrochemicals to GNP below 1.0; (c) the industry relies almost exclusively on naphtha as feedstock (over 98% of total feedstock use) and is therefore likely to be affected by the expected tightening of the demand/supply situation for naphtha in Asia; (d) since 1987 Japan has become a net importer of petrochemical products, through the combined effects of the mothballing of domestic capacity and the increase in competitiveness of other Asian producers; and the establishment of Japanese-owned subsidiaries in lower production cost countries with its output earmarked for the Japanese domestic market. (This relationship with Asian producers is further discussed in Chapter 4 and is thought to have implications in the future pattern of growth of the industry for low cost producers in the region.) If, on the other hand, Japanese producers go ahead with substantial additional cracking capacity, Japan may be able to reduce future imports of petrochemicals.

Table 3.13: JAPAN--DEMAND FOR BASIC AND DOWNSTREAM PETROCHEMICALS ('000 MT)

	1981	1988	Annual growth rate (88/81) (%)	Per capita demand (kg)
Ethylene	3,600	4,587 /c	3.5	37.6
Propylene	2,550	3,542 /c	4.8	29.0
Methanol	1,200	2,382 /c	10.3	19.5
Benzene	1,750	795	-10.7	6.5
LDPE	580	1,263	11.8	10.4
HDPE	800	795	-0.6	6.5
PP	900	1,507	7.6	12.4
PS	487	857	8.4	7.0
PVC	1,200	1,700	5.1	13.9
ABS	227 /a	416	9.0	3.4
SBR	508 /a	450	-2.0	3.7
PFY	314 /b	323 /d	0.4	2.6
PSF	320 /b	283 /d	-1.7	2.3

/a 1980 data.
/b 1982 data.
/c Source: East Asia Petrochemical Conference, 1988.
/d Source: Textile Organon: June 1988.

Source: Staff estimates

Table 3.14: PROPOSALS FOR NEW ETHYLENE CAPACITY IN JAPAN

	'000 MTY	Year on stream
Debottlenecking	450	1989
	500	1990
New Construction		
Mitsubishi Petrochemicals	500	1994
Maruzen Petrochemicals	300-500	1995?

Source: Fukui K. (Japan Development Bank), 1989.

IV. ESTIMATE OF COMPETITIVENESS

Factors Considered

In this section, the results of a comparative analysis of competitiveness in the production of petrochemicals are summarized. The factors reviewed to assess competitiveness included those related to economic, commercial and technical advantages.

Economic Competitiveness

The factors that were examined are: (a) the regional situation of feedstocks (naphtha and natural gas); (b) the advantageous geographical situation of the countries under analysis as it relates to the large domestic markets of Japan, China and the cluster of domestic markets represented by the pacific area countries; (c) the generally positive outlook for economic progress and trade in the region as currently forecasted by most analysts including the Bank; (d) the complementarity of trade patterns and the trade environment in the countries involved; and (e) the size of the domestic markets for petrochemicals.

Feedstock prices are a key factor of competitiveness in petrochemical production. For example, Naphtha costs were found to represent, after discounting by product credits, 28% of total production costs of well sized crackers in Korea. Naphtha is generally available to the region at competitive prices from Singapore, at quotations about US$20/ton below US Gulf Coast and only about US$6/ton above Persian Gulf prices.1/ Singapore prices are largely determined by demand in Japan, especially for petrochemicals. The historical data reveal (Annex 3.2) that Asian producers are presently at a disadvantage only relative to producers in the Middle East and have a significant advantage over US producers. The impact of these differentials on production costs of olefins and aromatics is discussed below.

While aromatic plants use whole range naphtha at prices presented above, naphtha based crackers for olefin production are usually based on light naphtha. No data were available on pricing of light naphtha in Asia, but because the petrochemical industry in the region (including Japan) accounts for a much larger share of naphtha demand than in the US, it has been conservatively assumed that there is no significant price differential between light and whole-range naphtha. This assumption appears consistent with quotations FOB Saudi Arabia for whole-range and light naphtha (mostly directed towards Europe where the share of petrochemical demand for naphtha is also much larger than in the US), which show no difference between the two types.

1/ Based on average prices for the period 1980-May 1989. The demand for high octane gasoline in the US has traditionally driven prices of whole range naphtha above quotations in other locations.

For purposes of the analysis, future naphtha prices consistent with the Bank views on future crude oil prices were utilized. These assume that oil will increase from US$14 per barrel in 1988 to about US$22 per barrel in the year 2000 (in constant 1988 terms). Assuming that refinery margins remain constant at levels which ensure adequate returns to refiners, naphtha prices in the regional spot market (FOB Singapore) would increase from about US$140 in 1988 to about US$200 by 2000.2/ Border prices for naphtha in each country were derived from this estimate by adding or deducting transport costs from Singapore, depending on the long-term outlook for the supply of Naphtha in each country. The projected price levels are summarized in Table 4.1.

Table 4.1: ASIA--PROJECTED ECONOMIC PRICES OF NAPHTHA
(by country, in 1988 US$/MT)

	1988	1990	1995	2000
Korea	150	165	178	212
India	152	167	180	214
China	150	163	176	210
Thailand	148	163	176	210
Malaysia	140	155	168	202
Indonesia	140	155	168	202

Note: Indonesia and Malaysia are long-term net exporters of naphtha, all others are long-term net importers. Naphtha prices refer to whole range naphtha. See Annex 3.2 for details.

For gas prices, valuation was based on the opportunity cost of gas and its fractions in each country. In countries or locations with large gas surpluses, the long run marginal cost has been adopted, while in those countries where gas has an alternative use, the value for the alternative use has been taken as the opportunity value of gas and its price projected for the period of analysis. The opportunity value of natural gas in each country varies significantly. Natural gas is valued at least as fuel oil equivalent in India, China and Thailand. Malaysia and Indonesia, however, have reserves far in excess of all present and foreseeable uses and the value of gas is thus tied to the cost of production and transportation to users plus a depletion premium. The projected ethane costs and the assumptions on which these are based are summarized in Table 4.2. The principles of ethane valuation and a description of the country situations is included in Annex 3. From the

2/ It is possible, however, that increased regional demand for naphtha from the petrochemical industry and the impact of lead phase-downs in gasoline expected in a number of Asian countries may result in higher refiner margins and may drive up regional naphtha prices.

industry point of view, both Malaysia and Indonesia have the best position in terms of naphtha and gas oil prices given the fact that both are long term net exporters of these materials and have already in place gas gathering, transportation and distribution systems; Malaysia and Indonesia also have the best outlooks in terms of the economic value of Natural Gas fractions. Because gas is difficult to transport and not easily tradeable, the valuation of ethane is also site-specific within a country. This is in particular relevant for Malaysia and Indonesia, gas produced in the remote Sarawak (Malaysia) and Kalimantan (Indonesia) areas has a substantially lower value at the site than gas transported to Java and peninsular Malaysia. The implication is that plants located in Sarawak and Kalimantan where gas is in large surplus would enjoy considerable advantages in feedstock costs over plants located in other parts of the countries if markets can be found for the methane fraction of the gas. Neither Malaysia nor Indonesia have large quantities of flared, economically recoverable, ethane-rich associated gas with a value close to zero. Consequently, since gas does not come as a by-product of oil production but has to be extracted at cost, ethane separation would only be economical if markets exist for the other gas fractions (methane, LPG) so that enough ethane can be separated to feed a world scale olefin plant.

Table 4.2: ASIA--PROJECTED ECONOMIC PRICE OF ETHANE
(by country in 1988 US$/MMBTU)

	1988	1995	2000
Korea	n.a.	n.a.	n.a.
India	3.3	3.7	4.4
China	3.3	3.9	4.7
Thailand	3.9	4.5	5.3
Malaysia (peninsula)	2.7	2.9	3.2
(Sarawak)	1.8	2.0	2.3
Indonesia (Sumatra)	2.1	2.3	2.5
(West Java)	2.3	2.9	3.1
(East Kalimantan)	2.1	2.3	2.5

n.a.: Not applicable, industry is naphtha-based or gas not available to industry.

India, China: Opportunity costs estimated at imported fuel oil equivalent plus separation costs.

Thailand, Malaysia: Opportunity value determined by its long-range marginal cost (includes gas collection, transportation, and separation costs).

Indonesia: Opportunity cost of ethane linked to production, distributions and separation costs since availability is not a constraint.

Source: Staff estimates. See Annex 3 for details.

Feedstock Availability. While ethane remains the preferred feedstock when available, the olefins industry has been increasingly building cracking capacity with flexibility to use a wide range of raw materials to take advantage of international market shifts in feedstocks and their relative prices (Chapter 2). However, the prospects of only the two major feedstocks, ethane and naphtha, have been analyzed. Feedstock availability is not expected to be a limiting factor in the region, at least as far as gas fractions are concerned, although there is a substantial cost variation among the countries.

Most of the subject countries have substantial reserves of gas and petroleum (Table 4.3). Malaysia and Indonesia have gas reserves in excess of 50 years. Thailand and India have also sizable reserves, large enough to meet current industrial and domestic demand for over 20 years but also with foreseeable demand is expected to exceed potential future supply. China, where natural gas is expected to be in short supply and Korea with no gas resources are expected to be at a disadvantage in the use of gas fractions and to continue to favor heavier feedstocks as raw materials.3/ China and Korea already produce 100% of their olefins from naphtha and other petroleum fractions. In the past complete reliance on naphtha has not been a limitation to expansion of domestic industries. For example, Korea, Taiwan and

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3/ Plans to develop a petrochemical industry in Hainan (China) based on NGL are still at an early stage and offshore gas development with foreign companies is still under discussion. Hainan will need substantial investments in infrastructure to parallel development in petrochemical industries.

Table 4.3: ASIA--OIL AND GAS PRODUCTION AND RESERVES, 1988

	Production		Reserves		Number of refineries
	Oil ('000 bbl /day)	Gas (MCFD)	Oil (Mbbl)	Gas (BCF)	
China	2,682.0	1,420	23,550.0	31,700	40
India	609.0	1,000	6,354.2	22,861	12
Indonesia	1,186.0	1,740	8,250.0	83,590	6
Malaysia	2,309.0	1,226	2,922.0	51,700	4
South Korea	--	--	--	--	6
Thailand	31.9	490	85.2	3,900	3
Others					
Brunei	139.0	n.a.	1,400.0	11,600	1
Japan	122.0	--	54.5	1,410	41
Taiwan	2.6	--	5.0	885	2

Mbbl: Millions of barrels.
BCF: Billions of cubic feet.

Source: Oil and Gas Journal, December 26, 1988, and staff estimates.

Japan, all lacking natural gas, keep a large and competitive industry, whose products are used as key inputs to a successful export oriented manufacturing sector. In the long term, though, naphtha availability for countries with no indigenous hydrocarbon resources is expected to play a limiting role in the expansion of the industry because of tighter supplies and higher prices. This seems to be particularly true for countries like Korea and Taiwan where the future demand for naphtha is expected to increase significantly over the next decade.

Geographical location can only be counted as an advantage if it translates into competitive access to markets. As discussed in Chapter 6, Asia as a whole is expected to remain a net importer of a wide spectrum of petrochemical products. Sizeable import markets are expected to continue in China, Indonesia and India; while prospects for increased share of imports in the domestic markets of Japan, and Taiwan are also anticipated. If tariff barriers and other import restrictions are discounted, freight charges will emerge as an important element in delivered costs. A spot check of current freight charges shows that established producers in Asia have a significant advantage in their own domestic markets due to the freight costs incurred by exporters (as much as 5-10% of FOB price, Table 4.4) against manufacturers in the US and Canada. It is also expected that future Japanese and Taiwanese manufacturers will continue to rely on competitive imports from subsidiaries or other companies located in the region, effectively creating a trading zone. Japan, Taiwan and South Korea have already invested in manufacturing facilities in Thailand, Malaysia and Indonesia (Table 4.5) while China and

India are trying to secure export/import marketing arrangements with producers and consumers in the region. The reduction in trade barriers within Asia will further contribute in favor of Asian producers.

Table 4.4: ESTIMATE OF FREIGHT CHARGES TO EAST ASIA (SINGAPORE) (in 1988 US$/MT)

	US (Gulf)	Western Europe (Italy or W. Ger.)	Middle East (Qatar or S. Arabia)	Canada (Alberta)	Japan	US Gulf FOB 1988 (Average price)
LLDPE	100	95	55	135	45	992
HDPE	100	95	55	135	45	1,080
Polypropylene	100	95	n.a.	n.a.	45	1,080
Styrene monomer	70	65	55	100	40	970
Ethylene glycol	75	70	50	100	40	965

Note: Exports from the Middle East into India would have lower freight charges than those shown in the table as would exports from US and Canada into China.

Source: Staff estimates.

Outlook for the Manufacturing Sector. The manufacturing sector of the developing countries in Asia and in particular in the Pacific Basin area has outpaced the overall growth of their economies over the last 15 years (compare data on Table 1.2 and Table 4.6) and in combination with the growth in exports has played a major role in the vigor of their economic performance. Government and Bank projections for future growth are also optimistic. An analysis of growth prospects for the economies in the target countries is beyond the scope of the report, and too complex to summarize here. For purposes of this study, projections for future growth of the manufacturing sector based on local development banks or government estimates were utilized (Table 4.7). These show that the growth in industrial output will easily surpass the expected growth in other regions. The favorable outlook for the manufacturing and industrial sectors provides an advantage to Asian producers that is lacking in other countries in Africa and Latin America: that is, the prospects for continuous growth and domestic market expansion.

Trade Patterns and Trade Environment. As a consequence of the impressive record of economic growth and the sustained growth in commodity and

Table 4.5: SAMPLE OF JAPAN'S OWNERSHIP OF PETROCHEMICAL PLANTS IN THE ASIA REGION

	Japanese company	Ownership	Local company	Products
Thailand	Mitsui	20%	Thai Plastics & Chemical	VCM
	Dainippon	49%	Siam Chemical	S. resins
Malaysia	Idemitsu Petro-chemicals	28%	Petrochemicals (Malaysia)	PS
Indonesia	Asahi Glass	70%	P.T. Asahi/Sventra	VCM, PC
	Dainippon	60.6%	P.T. Pardic Jaya	S. resins
	Nissho Iwai	10.5%		
	Tosoh Corp.	31.6%	P.T. Standard	PVC
	Mitsui	21.1%	Toyo	

Source: East Asia Petrochemical Conference, 1988.

manufactured exports, the Asian countries today account for over 75% of manufactured exports by all developing countries (Bhattacharya, 1989). Petrochemical trade has developed alongside the progress in manufactured exports, and a track of progressive graduation that links Japan to the newly industrialized countries (NICs), and the developing countries in Asia. Net trade in end user goods flows from Japan and the NICs toward other regions. As the NICs experience high production costs and reduce their comparative trade advantages, the least industrialized countries in the region vie to supplant them in exporting to third countries. For example, as Japan has moved toward the export of high-technology items such as computers, and electronics, the NICs have expanded the export of consumer appliances, while at the same time retracting from the textile export and rubber product markets where they are being replaced by the developing countries. The existence of a graduation in trade patterns provides stimuli and markets to the developing countries in the region for the progression of the chemical industry.

Another factor that is crucial in determining the outcome of proposed investments is the size of the domestic market. The Asian markets as a whole are growing at a fast rate (faster than any other market of comparable or larger size). But, within the region there are important differences in

Table 4.6: ASIA--HISTORICAL TREND OF ECONOMIC GROWTH /a

	1971-80	1980-87
Hong Kong	10.1	5.8
Taiwan	9.7	6.5
Korea	9.0	8.6
Singapore	9.1	5.4
Thailand	7.0	5.6
Indonesia	8.1	3.6
Philippines	6.5	-0.5
Malaysia	8.2	4.5
China	5.8	10.4
India	7.6 /b	4.6

/a Annual GDP growth rate in %.
/b 1965-80

Source: World Development Report, 1989, "Perspectives of Development in Pacific Economic Zone" by Trade Research Center of Japan Trade Association, 1985; "Annual Report '86" by Asian Development Bank.

market size and degree of market saturation that have the potential to affect the competitive position of local producers. The market size for olefins, aromatics resins, rubbers, and fibers in the six countries is summarized in Table 4.8. The largest domestic market in all categories is in China where the market size justifies the establishment of full scale units. Even at the expected rate of expansion of the local industry, the Chinese market will continue to outpace domestic production and dominate the merchant markets in Asia. Therefore its size and future growth will have a great deal of influence on the regional outlook. At the other end of the spectrum, Malaysia and Thailand have small size markets which on their own do not justify expansion or setup of new capacity.

Table 4.7: SELECTED PROJECTIONS OF INDUSTRIAL OUTPUT (1988=1.00)

	Index	1990	1995
Korea	Industrial domestic product	1.21	1.71
India	Manufacturing value added	1.14	1.61
China	Output value of chemical industry	1.28	2.15
Thailand	Value added for chemical industry	1.18	1.74
Malaysia	GDP /a	1.25	2.05
Indonesia	GDP /a	1.14	1.60

/a Used as proxy for industrial output.

Source: Bank economic data base; Bangkok Bank Monthly Review, 1988; China Ministry of Industry, 1988; Korea Institute of Engineering and Economic Studies, 1988.

Table 4.8: ASIA--MARKET SIZE FOR PETROCHEMICALS, 1988 /a ('000 MTY)

	Olefins	Aromatics	Resins	Rubbers	Fibers
Korea	2,300	700	1,300	200	1,300
India	800	400	600	50	200
China	2,800	1,500	2,700	300	1,300
Thailand	300	n.a.	300	10	100
Malaysia	200	n.a.	200	10	50
Indonesia	400	n.a.	350	10	200

n.a. Not available.

/a Based on the approximate 1988 demand for major products in each category.

Source: Staff estimates.

Commercial Competitiveness

Under this category, the following factors have been grouped: plant size, installation factor, utility and capital costs.

Plant Size. Economies of scale are important in the petrochemical industry, most countries in the Asia region have recognized this factor and supported the development of complexes with minimum scale criteria. In the case of India and China, despite efforts being taken to revamp and rationalize the existing units, wide sectors of the industry continue to operate small-scale plants that are generally associated with higher manufacturing costs. In both countries the long distances involved and the dispersed nature of the markets have led to the decentralization of production capacity and adoption of smaller-scale plants, other factors that affect selection of scale include marketing constraints, infrastructure available, implementation risks and environmental limitations. The production costs of ethylene crackers of different sizes reflecting current or expected practices were simulated under the conditions existing in each country. The sizes adopted for the ethylene crackers are presented in Table 4.9. These compare with crackers in the range of 450-600 MTY being implemented in the US, Western Europe and the Middle East.

Table 4.9: SELECTED ETHYLENE CRACKER CONFIGURATIONS

	Feedstock	Size ('000 MTY)	Remarks
Korea	Naphtha	450	Established industry, large domestic markets, strong financial position of companies involved.
India	Ethane/propane	300	Regional distribution is important. Market dispersed.
China	Naphtha	300	Domestic feedstock supply is a concern, market dispersed. Regional distribution is important.
Thailand	Ethane/propane	300	Relatively small market, new industry.
Malaysia	Ethane/propane	450	Very small domestic market. Must compete in the export market. Large feedstock supplies.
Indonesia	Ethane/propane	300	New Industry. Strong competition for feedstock

The installation factor is defined as the ratio of the required investment to set up a plant at a given location to the cost required to install it on the US Gulf Coast. The installation factor can be very significant in determining the production costs of petrochemical manufacturers in a country. The factors were estimated based on Bank data regarding previous projects in the petrochemical/chemical sector (India and Thailand), from estimates reported in the literature (Korea) or from estimates prepared by Bank staff but can only be considered as a gross theoretical approximation to individual real situations. The adopted installation factors (excluding the impact of taxation and duties on capital goods) are summarized in Table 4.10. High installation factors are associated with plants in India and Indonesia. While lower installation costs than those equivalent in the US Gulf, have been reported for Korea and Thailand. Installation factors may be high for a variety of reasons including (a) lack or limited domestic construction and engineering industry, (b) hindrances to adoption of modern technology and construction methods, (c) long construction times, and (d) lack of infrastructure.

Table 4.10: ASIA--OTHER FACTORS USED IN ANALYSIS OF COMPETITIVENESS

	Opportunity cost of capital (%)	Install factor /a	Shadow price factor /b	Currency	Exchange rate per US$ (1/89)
Korea	13.00	0.80	1.00	won	680.80
India	12.00	1.25	0.80	rupee	15.29
China	15.00	1.00	0.70	yuan	3.72
Thailand	12.00	0.95	1.00	bhat	25.39
Malaysia	12.00	1.00	1.00	ringgit	2.73
Indonesia	16.00	1.15	1.00	rupiah	1,743.00

/a Korea: Installation factor as reported by Korean Institute of Engineering and Economic Studies, 1988. It reflects historical ability to implement petrochemical projects below cost and in short periods of time. India: Installation factor reflects experience with previous petrochemical project and relatively long implementation periods. China: Although the last four ethylene crackers have all run into delays, the project costs have been generally kept at parity with international norms. Thailand: Reflects the experience with NPC-1. Malaysia: Is not yet a producer, but a 1.0 factor has been adopted based on the experience so far with the PP/MTBE complex and the record for other industries. Indonesia: Relatively high installation factor reflects long implementation periods and high costs associated with the methanol plants.

/b The use of shadow price factors for India and China has the effect of reducing capital costs by 14% and 9%, respectively (assumes that 60% and 30% of capital expenditures are from domestic sources, respectively).

Source: BESD data bank and staff estimates.

Other Factors. Opportunity cost of capital and utility costs including the marginal cost of electricity, cost of process and cooling water, cost of fuel oil and labor costs for each country were estimated by Bank staff (values adopted are reported in Annex 4) and used in the estimates of production costs.

Technical Competitiveness

Technical competitiveness is more difficult to quantify and therefore to introduce as an input in the estimate of production costs. The factors that intervene in the technical competitiveness include the technical and managerial experience in the field; the status of technology transfer of the manufacturing processes and the associated maintenance infrastructure; the customer support and extension services, in particular in the production of downstream products; the local engineering capabilities, the information services and planning systems. These factors reflect in the ability of local producers to operate at higher rates of production and in the lag times involved in the assimilation or introduction of process innovations that may further improve productivity. Technical competitiveness is also a factor in the reduction of installation factors, in the safety and quality standards, and in the success in early introduction of new processes and products. Countries like South Korea have a technical advantage over other producers in the region as shown by their ability to implement new capacity in relatively short periods of time; the successful introduction of new technologies (for example the large PP units pioneered in Korea using the newest available technology elsewhere); and, the track record on operation and maintenance of their units at Yeochon and Ulsan. This advantage translates into product differentiation, improved quality and reliable long-term operation and maintenance of their units.

Estimate of Production Costs of Petrochemicals

To estimate the production costs of petrochemicals, a simulation model has been utilized. The model (described in Annex 4) uses as input country-specific information, including country economic factors, economic and commercial advantages,and production inputs and then calculates the production costs, transfer prices (in the case of ethylene and benzene) and other components of manufacturing costs such as depreciation, interests and return on equity. Using a price projection,4/ it estimates the net present value and the internal rates of return. The model is designed to simulate the costs associated with different technologies, sizes and raw materials for each product and has been utilized to compare the relative economics in the manufacture of petrochemicals.

4/ Based on the assumption that levels will continue to cycle and will gradually decrease by 1995 at levels comparable to those posted in the US Gulf in 1985/86 (Annex 4) and assuming that this price level wil be valid for the Asia market as well.

The model estimates production costs for the target petrochemicals. It also calculates the economics of naphtha reforming required to estimate the costs of benzene extraction. The estimates for (a) ethylene, (b) benzene, (c) some olefin derivatives, and (d) some ethylene and benzene derivatives are reviewed in this section.

Ethylene Production Costs

To estimate ethylene production costs, it was first necessary to make some assumptions regarding likely configuration of olefin complexes in each country. To avoid distortions introduced by the projected cycling of prices of feedstocks and products it has also been assumed that all units start up in the same year (1991). These assumptions do not necessarily represent next in line crackers but are rather intended as a gross basis for comparison of the conditions of the industry in each country. For Korea, a large naphtha-based cracker (450,000 tpy) was used. This represents recent investments and is a reflection of the maturity of the industry, market size and feedstock situation in the country. For India, a 300,000 tpy ethane/propane cracker was used. Again, the selection represents current investments which reflect the dispersed nature and moderate size of the domestic markets and the impact of current industrial policy. For China, a 300,000 tpy naphtha cracker is utilized. This is a controversial choice, as small-scale naphtha units are expected to be generally associated with higher production costs and therefore be among the most vulnerable to future reductions in producer margins. On the other hand, the Chinese have been using this basic configuration, influenced by the difficulties in logistics, the size of the local markets, the available volumes of refinery feedstocks and the capabilities of local equipment suppliers. In Thailand, a 300,000 tpy ethane plant was adopted. This reflects the size of the first complex still under construction. Malaysia with no significant domestic market and abundant feedstock supplies must maximize its export competitiveness. Therefore a 450,000 tpy ethane-based unit has been adopted. Also, for Indonesia a 300,000 tpy ethane-based unit has been used. This reflects the limitations of feedstock apparent from the current negotiations to set up a cracker and the early stage of development of the industry (Table 4.9).

Based on the assumed, ethylene cracker configurations, the economics of ethylene manufacture for these units have been estimated for each country situation. High production cost and lower rate of return is associated, as expected, with naphtha-based crackers, notwithstanding the higher co-product revenues. Low IRR results are also related to comparatively higher installation factors, smaller scale and use of more expensive feedstocks. On the other hand, favorable results were generally obtained for ethane/propane-based crackers, in particular from large-scale operations in a country with low opportunity costs for ethane (such as Malaysia). The production costs, net present values, and IRRs for the simulated cracker configurations are presented in Table 4.11.

Table 4.11: ETHYLENE MANUFACTURE--ESTIMATED PRODUCTION COSTS /a AND RATES OF RETURN

Country	Feedstock	Size ('000 MT)	NPV (US$ mln)	Production cost (US$/MT)	IRR over 10 years (% p.a.)
Korea	Naphtha	450	135	468	18
India	Ethane/propane	300	85	477	16
China	Naphtha	300	78	496	14
Thailand	Ethane/propane	300	128	429	22
Malaysia	Ethane/propane	450	353	350	33
Indonesia	Ethane/propane	300	137	391	28

/a Production costs include return on investment.

Source: Staff estimates based on ASTIF Petrochemical Economics Model results.

The assumptions made on future ethylene market prices and the timing of the price cycle are critical to the rates of return. To test the response to depressed ethylene market prices caused by either overcapacity or economic recession (Table 4.12), an estimate has been made of the profit and cash margins obtained under lower ethylene prices. Figures 4.1 and 4.2 show how profit and cash margins are affected by reduced ethylene prices, Figure 4.1 for example shows the market price at which the different crackers break even in terms of profits. The results highlight the fact that all producers, independent of size and raw material would experience a serious erosion of profits if some of the recent past low price levels for ethylene are repeated in the future. The figures also illustrate that naphtha based producers are more sensitive to a drop in revenues, and would experience losses at ethylene prices of $350/MT or lower.

The economics of manufacture of ethylene have also been compared from the point of view of the cash operating costs and other production costs. The average costs over the plant life for units started in 1991 are plotted in Figure 4.3. The results show that gas-based crackers have a significant edge in production costs and are better suited to handle reductions in revenues and still remain viable than naphtha based plants. Low cost gas based manufacturers (Malaysia, Indonesia) could produce at between 70% to 80% of the level of high cost naphtha based manufacturers. The graph indicates the magnitude of competitiveness of ethylene producers in the region. The potentially lowest cost producers are Malaysia and Indonesia which could combine low gas costs with relatively low capital related costs. Next is Thailand with moderate capital costs and high gas costs. Korea is next, despite its use of naphtha which is partially offset by low capital costs. At the high cost side are India with high capital related costs and high gas costs and China which uses naphtha and operates at relatively small scales.

Table 4.12: CURRENT AND PROJECTED WORLD MARKET PRICES FOR OLEFINS
(1988 US$ per MT)

	1988 (actual avg.)	1990	1995	2000
Base case				
Ethylene	639	525	430	510
Propylene	430	430	400	460
Depressed market				
Ethylene	639	525	350	510
Propylene	430	430	350	460

Note: There is considerable uncertainty in projecting any prices for petrochemicals and the price variations described in Annex 4.2 are used only to illustrate the possible effects of a cycle that is difficult to predict but known to occur.

Source: SRI Chemical Price Update, 1988, for 1988 data and staff estimates for projections. See Annex 4.2 for projected petrochemical prices.

The assumptions made on future ethlyene market prices and the timing of the price cycle are critical to the rates of return. To test the response to depressed ethylene market prices caused by either overcapacity or economic recession, (Table 4.12), an estimate has been made of the profit and cash margins obtained under lower ethlyene prices. Figures 4.1 and 4.2 show how profit and cash margins are affected by reduced ethylene prices, Figure 4.1 for example shows the market price at which the different crackers break even in terms of profits. The results highlight the fact that all producers, independent of size and raw material would experience a serious erosion of profits if some of the recent past low price levels for ethylene are repeated in the future. The figures also illustrate that naphtha based producers are more sensitive to a drop in revenues, and would experience losses at ethylene prices of $350/MT or lower. These estimates should be used as a relative ranking of competitiveness rather than for the absolute values because of the many assumptions used in the projection of prices. The estimates of relative competitiveness in ethylene manufacture help to determine the competitiveness in the synthesis of ethylene derivatives. The model feeds this information into the downstream products in order to calculate their production costs.

Sensitivity Analysis. The naphtha crackers are particularly vulnerable to the oil market. Naphtha price increases strongly affect naphtha based crackers. For example, a 5% increase in naphtha prices reduces from 18% to 13% the estimated IRR for a 450,000 tpy cracker in Korea. Finally, a sensitivity analysis to size of the cracker has been prepared (Table 4.13). In Korea, for example, a naphtha cracker with a 650,000 tpy capacity was

Figure 4.1
RESPONSE OF ETHYLENE PROFIT MARGINS
TO DEPRESSED MARKET CONDITIONS BY 1995

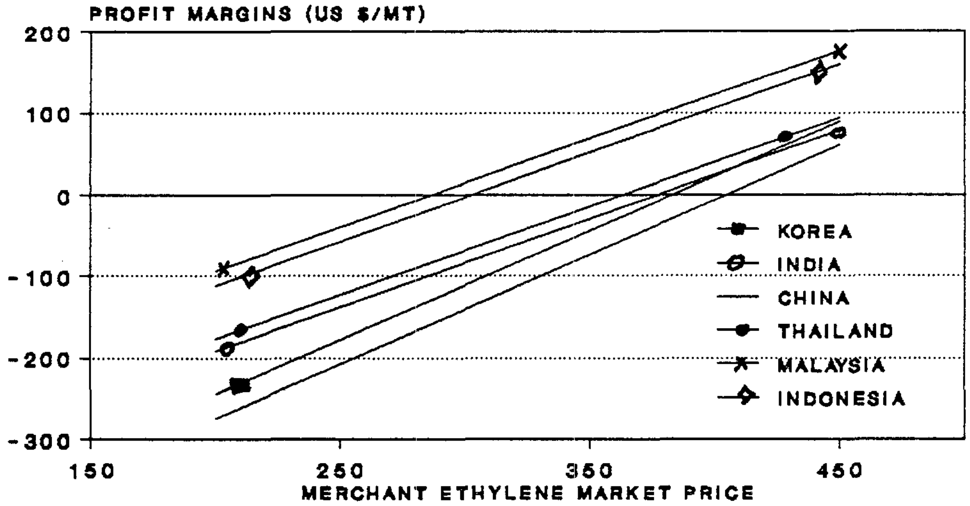
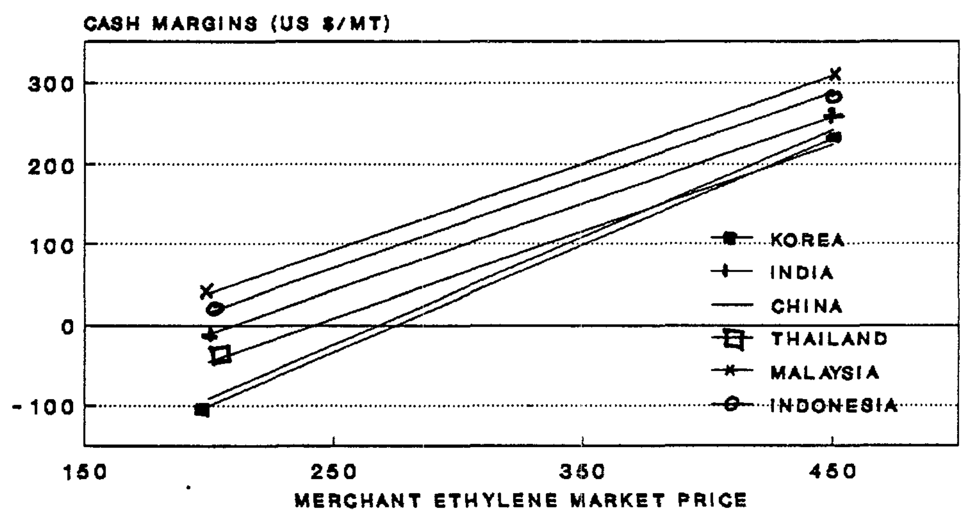


Figure 4.2
RESPONSE OF ETHYLENE CASH MARGINS
TO DEPRESSED MARKET CONDITIONS BY 1995



estimated to have an IRR of 21% compared to 14% for a 300,000 tpy cracker. Large naphtha crackers (650,000 tpy) efficiently operated are shown to compete with high-cost (US$3.5-4.0/MMBTU) ethane-based crackers (Table 4.13).

Table 4.13: SENSITIVITY OF THE ECONOMICS OF ETHYLENE PRODUCTION TO SIZE OF THE CRACKER

Country	Feedstock	Size ('000 tpy)	Estimated IRR
Korea	naphtha	300	14
		450	18
		650	21
Thailand	ethane/	300	22
	propane	450	27
		650	30

Source: Staff estimates.

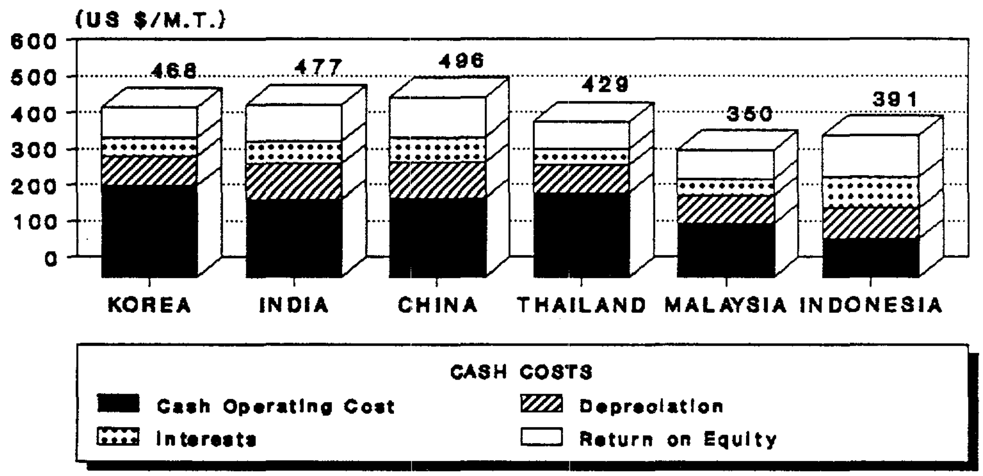
Aromatics

Aromatics (benzene, toluene and xylenes) are extracted after the reforming of naphtha (generally in refineries) or extracted from pyrolisis gasoline, a co-product of naphtha cracking in ethylene plants. Because of high octane values, aromatics are valuable gasoline components. Of the three aromatics, benzene has the highest value and is the most recovered for chemical uses. In the US, most aromatic production is derived from the reforming of naphtha in refineries. About 35% of reforming capacity could be used for aromatic extraction (BTX production).

Benzene Extraction Costs. To estimate the costs of benzene extraction, it was first necessary to make assumptions regarding the source of reformed naphtha (reformate) and to estimate its production costs.5/ It was assumed that for all countries the source of benzene is reformate obtained from full range naphtha reforming and the size of the operation is 450,000 tpy of reformate. Contrary to the situation with ethylene feedstock costs, the border prices for naphtha vary less than 10% among the countries and therefore feedstock costs have less bearing on comparative advantages while capital

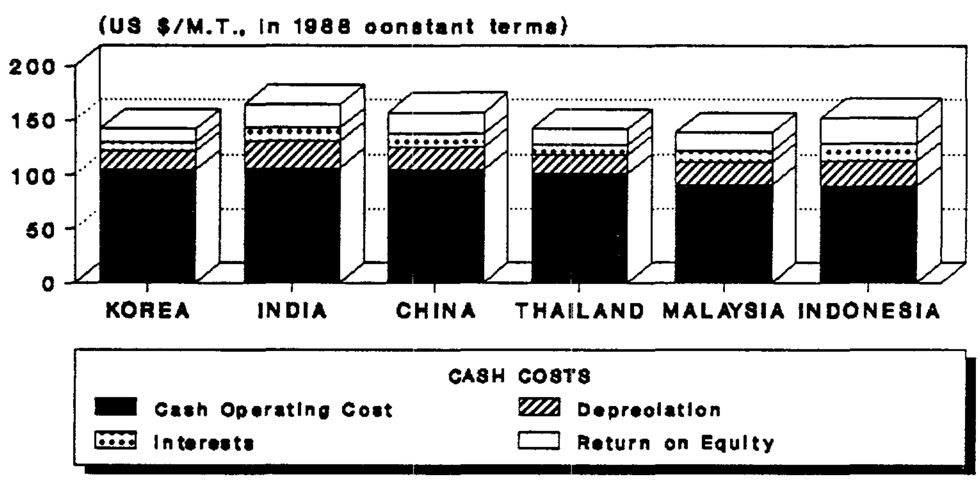
5/ Since not enough information was available on the actual configuration of reformers and BTX plants, the analysis aims only to an assessment of the cost of a theoretical new project of the same size and configuration in all countries and is intended only to illustrate the impact of feedstock costs and installation factors.

Figure 4.3
COMPETITIVENESS IN ETHYLENE MANUFACTURE
Based on selected cracker configuration



(In 1988 constant terms)

Figure 4.4
ESTIMATED COSTS OF NAPHTHA REFORMING
(From Full Range Naphtha, 100 RON)



Based on 450,000 MTPY Reformate capacity

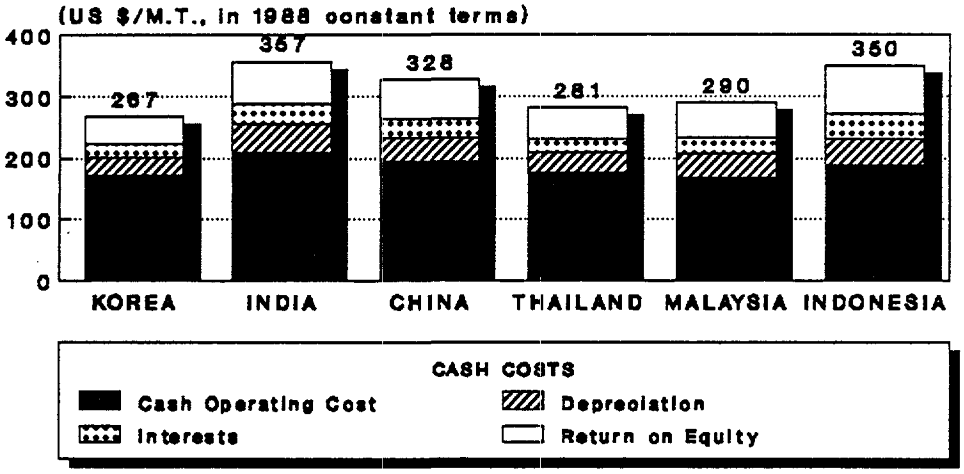
Assuming all other factors constant, the economics of naphtha reformers with a start up in 1991 have been estimated for each country (Table 4.14). The makeup of production costs are shown in Figure 4.4. The costs, size of the reformer and integration with refineries, as well as location relative to markets become relatively more important. results indicate that Korea, given its low capital costs, has costs comparable to naphtha surplus countries such as Malaysia. On the other hand, naphtha deficit countries with high capital costs are estimated to be at a disadvantage in the production of reformate. Similarly, the cost of benzene extraction was estimated for all the target countries. The producers of low cost reformate that can effectively pass the savings to integrated downstream benzene extraction units have a significant lead in production costs (Korea, Malaysia). High capital costs, high feedstock cost countries like India and China are estimated to remain on the high side of the cost range (Figure 4.5).

Table 4.15 gives an indication of the relative importance of feedstock and capital-related costs in the production of aromatics. The data point at the importance of scale and capital costs of the reformer and in the BTX plants. BTX plants are usually integrated with refineries because of economies of scale provided by the use of large reformers also used for gasoline production and to take advantage of well developed infrastructure in the refineries. Another reason for the importance of integration is the fact that the process uses refinery throughputs and a number of by-products normally return to refineries as feedstocks in other refinery operations. Geographical separation implies heavy internal transport cost penalties.

Commodity Polymers

4.29 A similar analysis has been conducted for the manufacture of commodity polymers. The sizes selected are midpoints in current practices and therefore do not obey directly to market size considerations. The only country without enough domestic market for plant of these sizes is Malaysia, but, again the assumption is made that Malaysia would vie for the regional export market. The results are summarized in Table 4.16. As it can be seen, the savings in ethylene manufacturing costs are reflected in competitive positions in the manufacture of polymers. This has been done by estimating a transfer price of ethylene for downstream producers, defined as the price level that allows the upstream producer a return on equity at a level 50% above the opportunity cost of capital. The most competitive producers are large-scale ethane/propane ethylene manufacturers that can effectively pass on savings to downstream producers. Although Korea starts up with a high transfer price for ethylene, other elements in its cost structure (lower installation cost, economies of scale) make up for some of the difference and results at a level comparable with low-cost gas-based producers such as Malaysia and Indonesia (Figures 4.6-4.8). The production costs are also affected by scale and technology. Sensitivity of production costs estimates to size of plant was estimated for LDPE and HDPE. The results shown in Figure 4.9 indicate that large scale manufacturers of PE can produce at levels equivalent to 70-80% of small scale producers. Technology selection is particularly crucial for PP, for which new processes (gas phase) represent considerable savings over established technology. Figure 4.10 compares the

Figure 4.5
COSTS OF BTX EXTRACTION
Using Sulfolane Extraction



(Based on a 200,000 MTPY capacity)

Figure 4.6
COMPETITIVENESS IN LDPE MANUFACTURE
Based on a tubular reactor, 100000 MTY

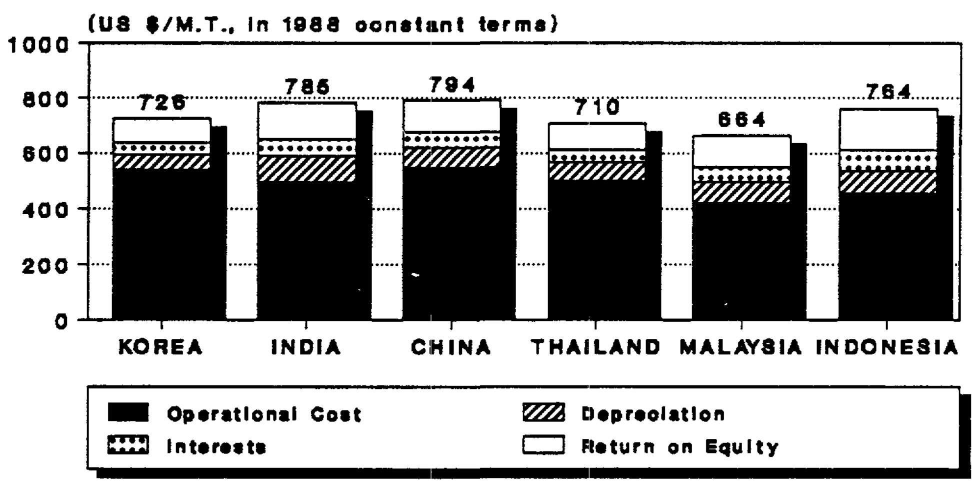


Table 4.14: REFORMATE AND BENZENE--ESTIMATED ECONOMICS OF MANUFACTURE

	Size ('000 tpy)	NPV (US$ mln)	IRR (%)	Production costs /a (US$/MT)
Korea				
Reformate	450	148	44	150
Benzene	200	152	41	277
India				
Reformate	450	121	28	173
Benzene	200	89	17	371
China				
Reformate	450	113	34	165
Benzene	200	95	25	341
Thailand				
Reformate	450	159	40	152
Benzene	200	153	35	293
Malaysia				
Reformate	450	171	40	146
Benzene	200	147	31	302
Indonesia				
Reformate	450	104	36	201
Benzene	200	67	21	334

/a Includes return on investment.

Source: Staff estimates.

estimated cash costs of full scale producers of PP using conventional and gas phase technologies. These are significant savings associated to the use of gas phase technology in the productino of polyproylene indicative of the increased competitiveness of new polypropylene manufacturers in the world market.

Other Downstream Products

Styrenics. For polystyrene, ABS and SBR which represent a commodity polymer, an engineering polymer and a synthetic rubber, respectively, the raw material costs are associated to both ethylene and benzene production costs. In all these cases, benzene prices and availability have a relative large

Table 4.15:
CHANGES IN PRODUCTION COSTS OF BTX EXTRACTION
CAUSED BY VARIATIONS IN KEY FACTORS
(US Gulf conditions)

	Change in production cost /a (US$/MT)
Naphtha freight	
$5	9
$10	18
$20	35
Size of reformer (base case: 745,000 t naphtha)	
400,000 tpy	17
1,200,000 tpy	-10
Size of BTX plant (base case: 425,000 tpy)	
180,000 tpy	44
730,000 tpy	-19
Installation factor/capital costs	
0.7	-38
0.9	-25
1.1	13
1.2	25
1.5	63
Capacity utilization	
Reformer 90%	8
80%	17
BTX plant 90%	10
80%	22
Combined 90%	18
80%	40

/a Production costs include return on investment.

impact in raw material costs through the use of styrene. Moreover, the market for styrene is somewhat independent from the ethylene market and follows cycles of its own. In the recent past styrene spot market prices have been very high and are expected to remain high in the short term. Vertical integration is therefore very important for styrenic producers when low cost feedstocks are available. To estimate production costs for these products it is necessary to project styrene production costs. As with the projections for olefin prices, these numbers are intended to be only indicative of future market cycles. (See Annex 4 for details.)

Table 4.16: COMMODITY POLYMERS--ESTIMATED ECONOMICS OF MANUFACTURE

Product (MT/year)	NPV (US$ mln)	IRR	Production costs (US$/ton)
Korea			
LDPE	89	20	726
HDPE	60	22	676
PP	31	22	665
PS	10	20	863
India			
LDPE	78	12	785
HDPE	60	18	696
PP	20	12	700
PS	5	10	912
China			
LDPE	56	12	794
HDPE	30	11	733
PP	25	19	671
PS	6	13	895
Thailand			
LDPE	108	21	710
HDPE	78	24	649
PP	31	19	667
PS	11	18	868
Malaysia			
LDPE	132	25	664
HDPE	110	32	584
PP	25	20	654
PS	11	17	
Indonesia			
LDPE	66	16	764
HDPE	65	20	665
PP	37	11	700
PS	6	12	903

Source: Staff estimates. LDPE estimates assume 100,000 tpy tubular process, HDPE assumes 100,000 tpy liquid slurry, PP assumes 75,000 tpy gas phase technology and PS, 30,000 tpy batch process. Production costs include return on investment.

The country specific estimated styrene prices were tied to the transfer prices of benzene from benzene extraction units and to the transfer prices for ethylene. In summary, this family of products illustrates a link to the aromatics and olefins sector in each country. In all these products, Korea comes out as the lowest cost producer, below low cost gas based producers and naphtha export countries such as Malaysia and Indonesia. This result is the combined yield of the degree of integration of the industry in both olefins and aromatics and the capital cost advantages (Figures 4.11-4.12).

Competitiveness in the Export Markets

In the section above, the relative competitiveness of Asian producers within Asia has been estimated. While the results are highly relevant for difficult to transport materials such as ethylene and others with little or no international trade, for many petrochemicals international trade is expected to play a very active role. As competitors, low-cost gas-based producers in three different locations have been selected. These are: Western Canada, US Gulf and Saudi Arabia which are expected to be among the lowest cost producers outside of Asia. The production costs of these locations have been estimated for key olefins and derivatives (ethylene, benzene LDPE, HDPE and PS) and for benzene using the same assumptions employed in the previous section (Table 4.17 and Figures 4.13 and 4.14). Although Saudi Arabia is the lowest cost producer, it is the US Gulf coast that is used as a benchmark because of the larger share of the market tapped by US producers (about 31% of all olefins, 34% of all plastics, and 37% of all synthetic rubbers are produced in the US and Canada) and because Saudi Arabia is not expected to increase its gas based capacity in the foreseeable future (additional ethane availability is tied to increased production of oil). Production costs in Canada are expected to remain marginally higher than in the US because of comparatively higher capital costs and higher internal freight costs.

Table 4.17: ETHYLENE, ETHYLENE DERIVATIVES, REFORMATE AND BENZENE: ESTIMATED ECONOMICS OF MANUFACTURE BY LOW COST PRODUCERS OUTSIDE ASIA

		Production cost		
	Size	Western Canada	US Gulf	Saudi Arabia
		(US$/ton)		
Ethylene	450	408	396	346
LDPE	100	701	668	683
HDPE	100	610	585	567
PP	75	629	621	646
PS	30	799	780	803
Reformate	450		127	101
Benzene	200		243	817

Source: Staff estimates. Production costs include return on investment.

Figure 4.7
COMPETITIVENESS IN HDPE MANUFACTURE
Based on Slurry Technology, 100,000 MTY

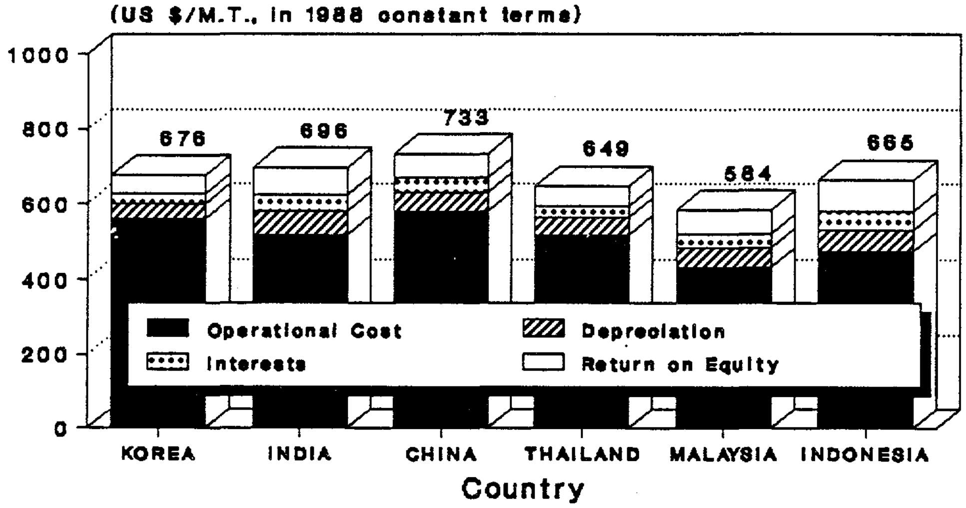


Figure 4.8
COMPETITIVENESS IN PP MANUFACTURE
(Gas phase technology, 75,000 MTY)

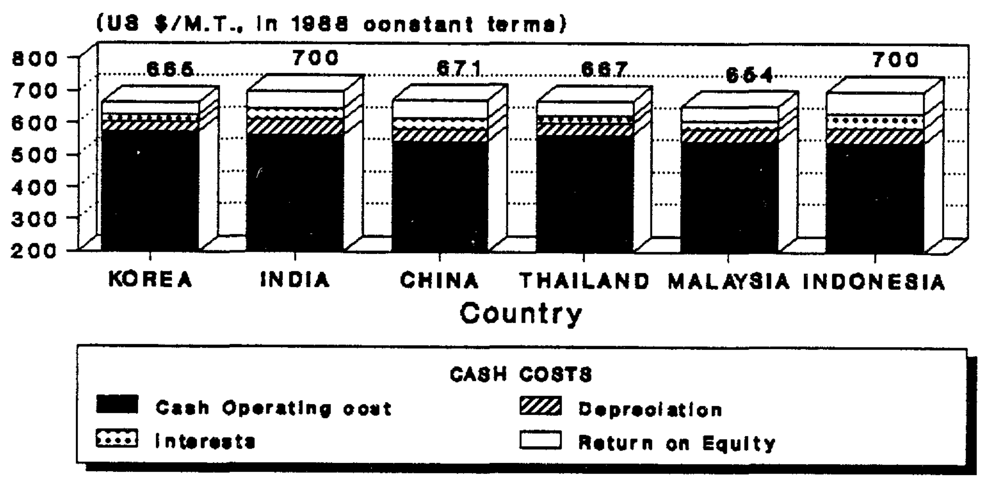
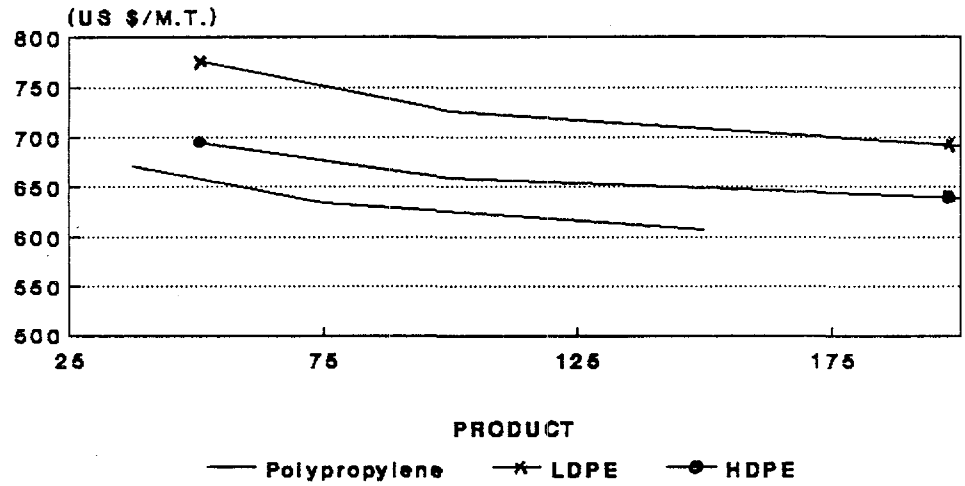
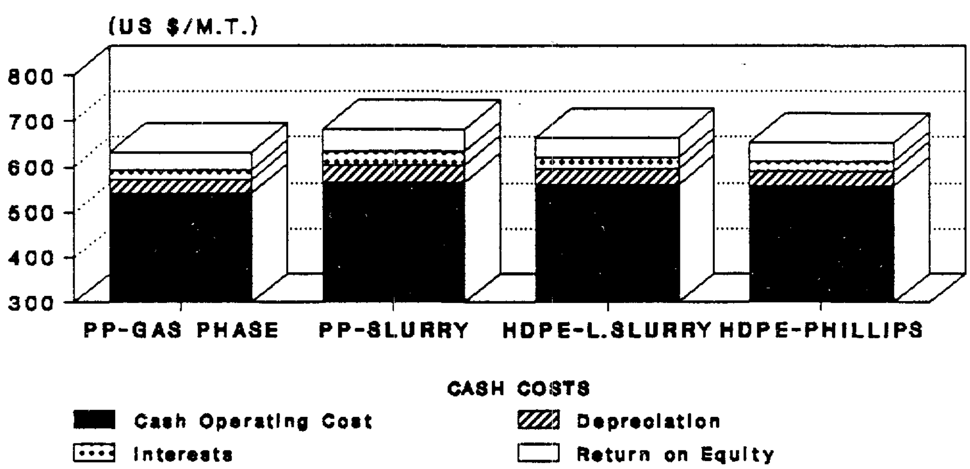


Figure 4.9
EFFECT OF SCALE ON PRODUCTION COSTS
(Typical E. Asian conditions)



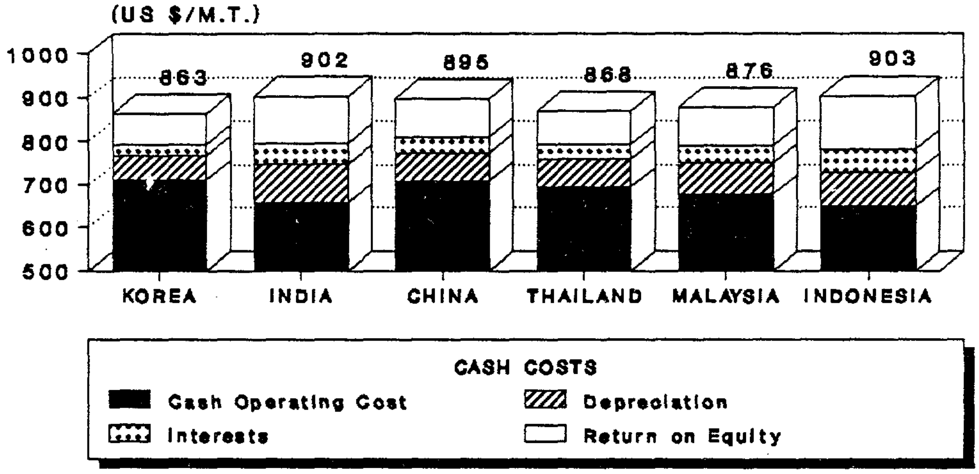
(In 1988 constant terms)

Figure 4.10
EFFECT OF TECHNOLOGY ON PRODUCTION COSTS
(Typical E. Asian conditions)



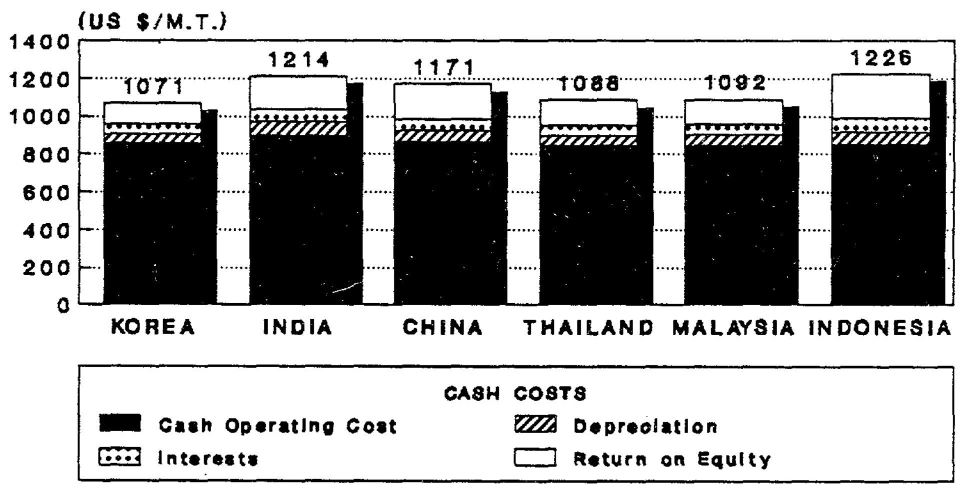
(In 1988 constant terms)

Figure 4.11
COMPETITIVENESS IN PS MANUFACTURE
(Batch Reactor, 30000 MTY)



(In 1988 constant terms)

Figure 4.12
COMPETITIVENESS IN ABS MANUFACTURE
(Emulsion Polymerization, 50000 MTY)



(In 1988 constant terms)

Figure 4.13
ETHYLENE PRODUCTION COSTS
(Low cost producers outside of Asia)

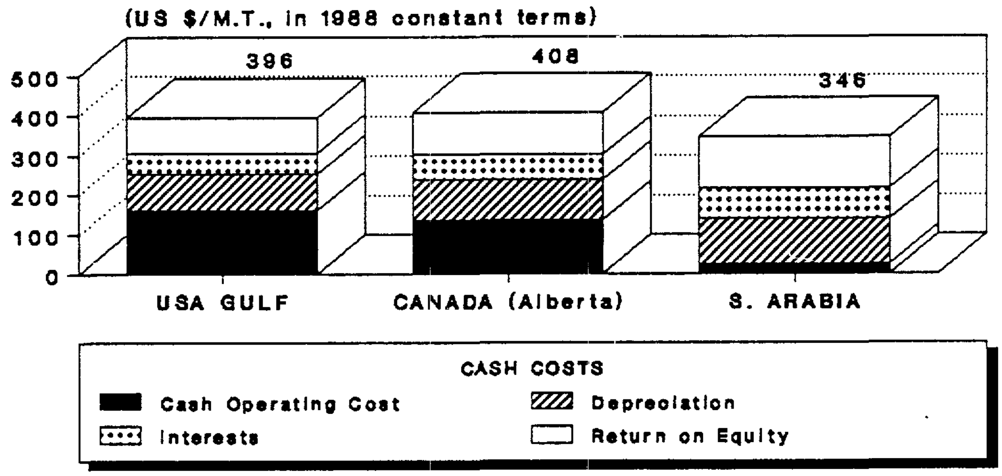
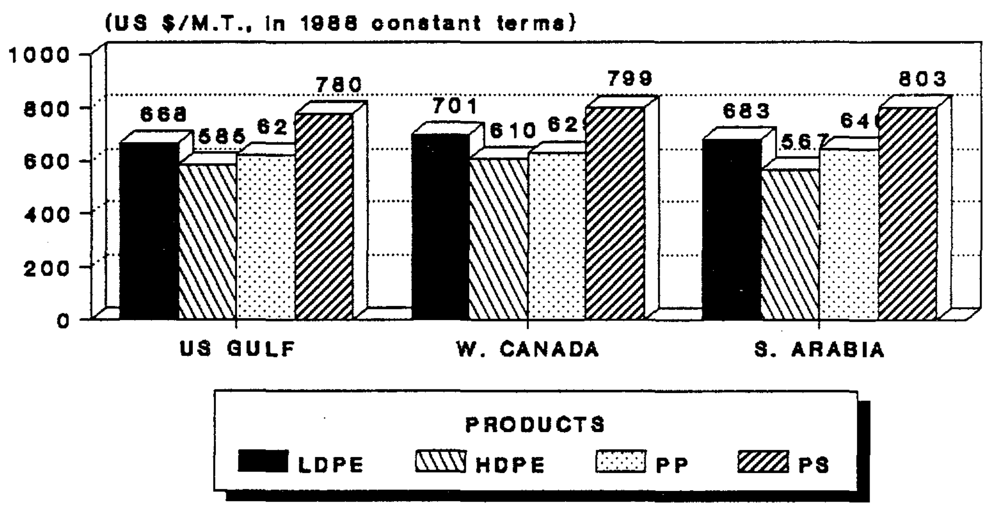


Figure 4.14
PRODUCTION COSTS OF DOWNSTREAM PRODUCTS
Low cost producers outside Asia



Advantages of Asian Producers in Aromatic Production

Aromatics are liquid chemicals that are relatively easy to transport. The following table shows differences in feedstock prices, capital costs and capacity utilization that can compensate for freight costs from various locations. The maximum naphtha price difference between the Middle East and Asian net importers ($23) is compensated by the cost of transport of BTX from the Middle East. Even if naphtha prices were to increase more in Asia than elsewhere, it is unlikely that price differences would reach levels that would jeopardize the competitive position of Asian producers on their own market (with the possible exception of Middle East producers). In addition, a number of Asian countries are expected to derive significant advantages from their ability to build plants quickly and cheaply and operate them at capacity.

Trade Scenarios Involving Asia based Producers

Three different trade scenarios have been analyzed to illustrate the relative advantages of Asian based producers. These are:

(a) Competition for a large domestic market in the East Asia region (China). In this case, it has been assumed that producers in Malaysia, Indonesia, Korea and India compete for the Chinese domestic market against low cost producers outside Asia. Indicative freight and handling charges were added to the production costs of all manufacturers. The results show that overall Malaysia among Asian producers would be in the best competitive position to enter export markets within East Asia. Its potentially low cost of production and favorable location would benefit future potential Malaysian based manufacturers. Middle East producers could outcompete regional producers if production from new gas based units is available for exports to Asia (Table 4.20). Countries with high costs of production such as India do not seem to be in a position to compete for exports to Asia locations.

(b) Imports to domestic markets in Asia from spot merchants in the Middle East and the US Gulf. In this case, imports from inexpensive producers from outside the region are compared to local production costs in several Asian countries. Border prices for resins have been estimated from sources in the Middle East and US Gulf for those markets that are expected to step up production to meet most domestic needs (Thailand, Korea, India, Indonesia). The production costs are compared with border prices to assess the rationale for domestic production. The results confirm that high-cost producers in Asia are marginally competitive in their own markets and that imports should be considered as a viable complement to domestic production (Table 4.21).6/ This is particularly true in countries like India and China. In South Korea, Malaysia and Thailand the US-based producers competitive edge is compensated by capital costs and freight charges.

(c) Exports to lower markets outside the region from Asian-based producers. Under this scenario, the cost of exports from Asian-based producers with an export oriented outlook have been compared with estimated costs of domestic producers in the US Gulf. The results are summarized in Table 4.22. The data conclusively show that based on the assumptions used in this report, Asian-based producers are not able to compensate for freight costs when exporting to market locations outside the region.

Table 4.20: ESTIMATE OF PROJECTED DELIVERED PRICES (PLUS RETURN AND FREIGHT) TO A CHINA EAST COAST LOCATION (1990's AVERAGE CONDITIONS) (US$/MT)

	Korea	India	Malaysia	Indonesia	Saudi Arabia	US Gulf
LDPE	771	835	709	814	738	768
HDPE	721	746	629	715	622	685
PS	908	962	921	953	858	880

Note: Freight charges were estimated as $45/ton for Korea, $50 for India and Indonesia, $45 for Malaysia, $55 for S. Arabia and $100 for US Gulf.

Investment Timing

Because of the large outlays required by petrochemical plants and the cyclical nature of the industry, the timing of the investment and the actual start up date are important for the economic performance of the units. Start up at the bottom of the price cycle can result in an impaired financial situation for the lifetime of the plant. The section on production economics was developed under the basic premise that all the projects have a similar start up schedule. In the paragraphs below, the current proposals for

6/ In India and China, the production costs are somewhat higher than the US costs plus freight for the conditions selected. The results of the analysis imply that if the US is the price setter China and India will have to lower their returns in order to compete for their own markets.

Table 4.21: COMPARISON OF PROJECTED US GULF DELIVERED PRICES AND LOCAL PRODUCTION COSTS IN ASIA DOMESTIC MARKETS (1990s AVERAGE CONDITIONS) (US$/MT)

	China	Korea	India	Thailand	Indonesia	US Gulf
LDPE	794	726	785	710	764	768
HDPE	733	676	696	649	665	685
PP	671	655	700	667	720	721
PS	895	863	912	868	903	880
SBR	1,207	1,107	1,231	1,147	1,208	1,150
Benzene	341	277	371	293	334	285

Note: To simplify estimates, it has been assumed that freight from the US Gulf to all local markets is the same.

Table 4.22: ESTIMATES DELIVERED PRICES TO THE US GULF (1990'S AVERAGE CONDITIONS) (US$/MT)

	Malaysia	Indonesia	Korea	US Gulf
LDPE	774	864	826	668
HDPE	694	765	776	585
PS	986	1,033	963	780

Freight charges from Asia to the US Gulf were estimated at US$100/MT for Indonesia and Korea and US$110/ton for Malaysia.

Source: Staff estimates.

ethylene crackers are divided into groups according to the timing factor and their prospects are discussed under this perspective.

As discussed in Chapter 2, the inherent investment cycles of the sector in the US were put in evidence with the surge in announced investments during 1989 after a long period of no activity that lasted over three years. In Asia, a similar pattern has occurred. A great deal of production capacity is now on the drawing table. Some projects due to come on stream in 1989 were actually conceived and started at the bottom of the last cycle. Whether the results of clear foresight, or the end products of a long gestation period, or rather because of isolation from the trends in the world market, these units are bound to benefit the most from the current upswing of the industry. The plants included in this group are the Yeochan and Ulsan expansions in Korea, the Nagothane complex in India, the Beijing plant in China and NPC-1 in Thailand. All these plants are projected to enjoy relatively strong market in 1989 and a declining but still profitable situation in the early 1990s. Their profitability will be strengthened by their timing.

A second group of plants has been an early starter in the current cycle of events. Even though the investment decisions of these units have been riding with the cycle, their plans have crystallized or translated into actual construction schedules much earlier than their competitors. The plants currently being built in Asia are in this position and will probably start up with prices at the average levels of the cycle. These units do not have the advantage of the previous group but are not projected to be worse off than the industry average under depressed market conditions.

Finally, one has to consider those units that miss the cycle and start implementation when prices collapse. A classic example is the first Yeochan unit in Korea. Not only did the investor experience serious difficulties but it also affected the rest of the industry by delaying market development and syphoning funds out of alternative investments. Clearly this is an example not to be followed. These proposals are also likely to be the first to be scrapped or delayed if the market conditions deteriorate before actual investments are committed.

Summary

The results of the analysis show that the countries in the region are at various degrees of competitiveness in the production of petrochemicals. The following general conclusions are drawn from the calculations and discussions:

(a) For Asian countries building olefin capacity for their domestic markets, a US$100 freight advantage shifts the "permissible" cost of feedstock (that is, the cost of ethane or naphtha at which domestic production would still compete with landed cost of US imports), up by about US$2.0 per million BTU for ethane, and increases the switching value of naphtha (relative to US ethane prices) by about US$50, but only if everything else is equal, in particular, cracker sizes, capital costs and capacity utilization similar. Once the particular conditions are factored in low capital cost countries with large plant capacities enjoy a higher advantage. Some crackers built for domestic markets are competitive for ethane costs of up to about US$4.5 per million BTU and for naphtha costs of up to $200 per ton.

(b) For Asian producers wishing to produce for export, inside the region to, say, China, the freight advantage is substantially less. They have a chance to compete if ethane costs are less than US$3.5 per million BTU today, increasing to no more than US$5 by the end of the next decade. With respect to naphtha-based operations, product freight advantages of Asian exporters to other countries n the region could still permit naphtha costs higher than in the US by some US$20 (while maintaining competitiveness with US ethane-based operations of the same size) as long as the cost of naphtha remains at less than US$200 per ton. This advantage, however, is likely to be available to most Asian producers, and in fact would justify the setting up of naphtha-based production for domestic use. Therefore, unless capital costs are below US costs, or capacity utilization consistently above, only the cost of ethane truly determines comparative advantage for exports to other countries in the region.

Capital costs and capacity utilization are as critical as costs of feedstock. Capital costs one third above US Gulf Coast costs can entirely wipe out a $2 ethane cost differential. Operating crackers at 80% of capacity when competitors operate at 100% has a similar impact. From the above analysis, the following tentative conclusions can be drawn, with respect to investment plans in the six countries.

Korea is quite competitive in the production of aromatic derivatives, olefin derivatives and secondary downstream products (such as ABS and SBR) where its advantages in capital costs, shorter implementation periods and higher productivities compensate for the relatively high feedstock costs. This is clearly the reason why the industry has integrated and why the Korean producers have the most to gain from a strategy that maximizes value added.

Malaysia and Indonesia are potentially the lowest cost producers for olefins and aromatic feedstocks. Malaysia, with ethane costs projected at between $2.7 and $3.2 per million BTU (peninsular Malaysia) and installation factors of about 1.0, is projected to be a good potential location for the industry. Timing though may have an important role in defining the country outlook. The delays in implementing the olefins complex may force it to miss the high revenues part of the cycle and face start up when prices are projected to be significantly lower. Indonesia, with ethane costs in Java at around $3, but with high installation costs could compete with US imports, but only for its domestic market. Export competitiveness for Indonesia is probably conditional on reducing capital costs substantially, unless export-oriented plants of large size can be built in North Sumatra, where ethane costs would be substantially lower ($2 to $2.5). If such plant can be built and if capital costs can be brought down, Indonesia could be in a strong position as an exporter to the region.

Thailand is shown to have the potential to compete with the lowest cost producers in downstream olefins and aromatics. Even though the industry is still at a very early stage, it has the makings for a strong competitive position in the region through the export of end user products. Its competitive position is the result of efficient implementation, thorough integration, careful location and timing and low capital costs.

China and India are at the high cost range in the industry. In China the feedstock situation and the relatively long implementation periods make it a relatively high cost producer of basic petrochemicals. Still, China can be competitive with production from naphtha for domestic use; Chinese authorities, however, may wish to consider increasing average plant sizes above the current average of 300,000 tpy. In India, the advantages provided by the use of gas allow for the production of basic olefins at moderate prices, but high capital costs and long gestation periods contribute to increase its cost of production of downstream products. Although local manufacturers can compete for the Indian domestic market, with the current cost structure it will be very difficult for Indian producers to compete in the export market.

V. THE POLICY FRAMEWORK

All the governments in the countries under analysis have intervened in the establishment of their petrochemical industries and have sought initially to shield it from import competition. Today, however, the policy framework is very different, and there is a general tendency towards liberalization. In some countries like India except for synthetic resins, the policy environment remains restrictive and protective, in others like Korea, it is the opposite. Invariably, the policy framework reflects: (a) the stage of development of the petrochemical industry; and (b) the export orientation of the economy. Government interventions have been prevalent in a number of areas: (a) controls over the pricing and availability of feedstocks, (b) tariff and import licensing, (c) protection against competing imports, (d) capacity licensing, (e) structure and ownership of the industry, (f) special investment incentives, and (g) concessional financing. Table 5.1 summarizes the key policy tools used in the six countries. Each element is discussed in the paragraphs below.

Price Controls

With the exception of China, direct administrative controls over prices of petrochemical products have not been prevalent in the countries under analysis. Prices have generally been left to market forces, subject to indirect intervention in price setting through tariff protection and taxation and capacity licensing policies. These interventions have in some cases resulted in distortions in price levels. In India, prices of products are high, due to prevailing high tariffs and to excise taxes at the federal, state and local levels. These taxes vary from 15% to 40% for plastics and rubbers.1/ For fibers, however, excise taxes are product specific and extremely high, sometimes doubling ex-factory prices. These high prices have been a constraint to faster demand growth and a factor in the low capacity utilization of the synthetic fibers industry. In China, prices of polymers and fibers are reportedly controlled at levels lower than their opportunity cost. A two-tier pricing system has been established under which output not covered under national or provincial plan allocations may be sold at "market" prices. In most cases there is no control on upper price levels, but prices do reflect much more accurately market conditions than the fixed prices that apply to allocated production. Whereas the fixed prices for allocated production are generally significantly below world prices, market prices are generally higher. But not enough information is available on levels and control mechanisms to assess the impact of such policies. In South Korea, prices must be submitted for Government approval whenever a single company controls over 50% of the market, or when three companies control over 70% of the market. These regulations, combined with a desire to soften the impact of

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1/ Part of the tax is recoverable under the Modified Value Added Tax system.

Table 5.1: ASIA--SUMMARY OF KEY POLICIES IN THE PETROCHEMICAL SECTOR

	India	China	Indonesia	Thailand	Malaysia	Korea
Feedstock Pricing						
Natural Gas	Under definition	Not applicable	Not applicable yet	Opportunity Cost	Not Applicable yet	Not applicable
Naphtha	Much higher than Opportunity Cost	Lower than Opportunity Cost	Slightly lower than Opportunity Cost	Opportunity Cost	Opportunity Cost	Opportunity Cost
Product Pricing	Market pricing, subject to moderate to very high excise taxes and import tariffs	Controlled prices, possibly below market value	Market pricing, subject to import tariffs	Market pricing subjet to import tariffs	Market pricing subject to import tariffs	Market pricing, subject to Govt. intervention on case per case basis; subject to import tariffs.
Capacity Licencing	Yes minimum size requirements	Yes-minimum size requirements	Yes	Yes	Yes	Will no longer be required starting 1990
Import Licensing	Yes, except major polymers (under Open General License)	Yes	Import monopoly removed at the end of 1988	No	No	No

	India	China	Indonesia	Thailand	Malaysia	Korea
Tariff Protection						
Nominal Protection	Moderate to very high, wide dispersion	Moderate	Low to moderate, higher for locally produced items (infant industry protection scheme)	Moderate	Low to Moderate	Moderate (1988) to Low (1993)
Effective Protection	wide range, generally very high sometimes negative	Moderate to High	Wide range, high on a few domestically produced items	Moderate to high	Low	Low, good consistency
Integration of Olefin Complexex	Yes	Yes	Under definition	No	Under definition	Not initially yes now
Public/Private Ownership of Olefin Complexes						
Upstream	First 2 crackers: private Third and 4th crackers Public	Public (SINOPEC)	Under definition	Public majority	Under definition (probably public majority)	Public initially now private

	India	China	Indonesia	Thailand	Malaysia	Korea
	New Crackers under planning: Private					
Downstream	Same as upstream	Public (SINOPEC) and other companies	Under definition	Private	Under definition (probably private)	Private
<u>Investment Tax Incentives</u>						
-Income tax Exemptions or reductions		Yes for joint ventures and investments in Special Economic Zones and Coastal Cities	No	Yes	Yes	Yes initially,
-Exemptions from duties on capital costs and raw materials	No	Yes, as above	Yes but limited custom free zones up to 80% of equity	Yes	Yes	No
<u>Foreign Equity Participation</u>	Possible for up to 40%	Yes, in downstream joint ventures. Also possibility of wholly-owned companies in SEZ and coastal cities.	Limited to joint ventures- Majority domestic ownership mandatory after 10 years	Possible, but capacity licensors privilege majority local ownership	Possible but licensors likely to privilege majority local ownership	No restrictions

price fluctuations on indirect exporters have resulted in domestic prices being kept at levels lower than international equivalents.

Feedstock Pricing

The cost of feedstock is one of the important determinants of competitive advantage. Therefore, pricing or taxation policies which result in significant differences between financial prices of feedstocks and their opportunity costs may distort such advantage and artificially favor the choice of one feedstock over the other.

Pricing of Naphtha. The current naphtha prices paid by the petrochemical industry in 1988 are summarized in Table 5.2. The FOB Singapore price in 1988 was about US$140 per ton. Since Malaysia and Indonesia are net exporters of naphtha and crude oil, domestic prices of naphtha are likely to be about the same or slightly lower than the FOB Singapore price. Naphtha prices tend to be at, or somewhat below, their opportunity cost in Indonesia and China and generally at opportunity cost in Malaysia, Thailand and Korea, but it is above opportunity cost in India. The high naphtha price in India is due to (a) high retention prices paid to refineries, (b) heavy incidence of taxation, and (c) high contributions to a freight equalization pool for all refinery products.

Table 5.2: CURRENT NAPHTHA PRICES PAID BY PETROCHEMICAL PRODUCERS

Country	Price
India (mid-1988)	US$277/ton (price paid by IPCL including local taxes)
Indonesia	85% of FOB Singapore
China	US$120/ton
Korea	CIF plus 2% duty (maximum)
Malaysia	CIF (maximum)
Thailand	CIF (no sales presently)

The setting-up of naphtha prices at levels which ensure minimum margins to the refining industry, without reference to the international price was a policy in Korea until 1986. The combination of high naphtha prices and low international petrochemical prices resulted in heavy financial losses to the industry, in spite of the 30% protection still prevailing at that time. In 1985, the Government deregulated naphtha prices. Today, there are no controls on prices and imports of naphtha.

Countries where both natural gas and naphtha are available as feedstocks are faced with the task of fixing prices in a way that does not artificially provide a competitive edge to production from either gas or naphtha. Price setting for gas fractions (C2/C3) iss relevant for Thailand and India. In Thailand the first NPC complex will use gas fractions, but the second complex, presently under planning, would possibly use a range of other feedstocks. In India, if gas prices to the petrochemical industry were to be set at opportunity value while naphtha prices are kept at present levels (which are way above border prices), naphtha-based complexes would have feedstock pricing penalties relative to gas-based operations. It would therefore be important that naphtha prices be lowered to their opportunity value by the time gas based capacity comes on stream. In Thailand, on the contrary, there appears to be a desire in principle to let naphtha be imported at its CIF value and to set the price of gas fractions at their opportunity cost.

Pricing of Gas Fractions. Natural gas components most commonly used for petrochemical production are ethane (C2), propane (C3) and butane (C4). Propane and butane also form part of the normal composition of liquefied petroleum gas (LPG), a fuel widely used by the household sector. LPG is easily tradable in pressurized vessels and tankers and has a large international market. Ethane, on the contrary, is more difficult and expensive to recover and is not traded internationally, except in the form of Liquefied Natural Gas (LNG), together with methane and other fractions. When not used in petrochemical production, ethane is left in natural gas and burnt as fuel. Thus, when the Petrochemical industry utilizes propane and butane that can be economically recovered for LPG production, the opportunity value of these fractions is the border price of LPG. When the industry utilizes C2 fractions (often together with some C3 and C4 not economically advantageous to recover), then the opportunity value of these fractions is linked to the value of natural gas. The key factors in the determination of ethane value were discussed in Chapter 4 and further detailed in Annex 3. Essentially, the economic value of ethane is equal to the opportunity cost (or value) of natural gas, plus the cost of ethane separation.

In Thailand, India and China, the opportunity value of natural gas is estimated as fuel oil equivalent (Chapter 4). The value of ethane is thus in the range of US$3.0-4.0 per million BTU. In Indonesia and Malaysia, where gas is generally in surplus, the cost of ethane has been estimated at between US$1.5 and US$3.0 per million BTU. In Korea, there is no natural gas and the industry depends entirely on imported feedstocks. None of the six countries is presently producing olefins from gas feedstocks, consequently, gas pricing policies for petrochemicals are not established. However, production is soon to start in India and Thailand and government agencies are now in the process of selecting the most suitable formulas. In Thailand, the selected formula calls for ethane prices in line with the price to power plants (which seems to be in line with the opportunity cost of gas), plus a separation charge. The financial price is therefore expected to reflect the economic value of ethane. In India, the price of C2/C3 fractions (over 90% ethane) has just been established based on the current landfall price plus separation costs.

Trade Policies

Import Licensing

Countries where most of the industry's clients are direct or indirect exporters tend to have liberal policies with respect to imports. Malaysia, Thailand and Korea no longer have licensing requirements for petrochemical products (Korea phased out its import licensing system between 1984 and 1987). Indonesia, which used to have a trade monopoly in charge of all petrochemical imports and internal distribution, has recently liberalized imports as well (licensing is still required but the import monopoly was abolished in 1988). India still has a restrictive import regime: only recently were imports of plastic polymers by trading houses allowed; however, licensing remains the rule for practically all other materials and is in fact binding, whether the products are on the "limited permissible" or "restricted" lists. It is up to the importer to prove that the materials are not available from local sources. In addition, the import of a number of petrochemical materials are "canalized," i.e., monopolized by a number of public institutions.

Import licensing of petrochemical feedstocks (naphtha, LPG) is more widespread, generally requiring clearances from public companies or other public institutions in the refining sector. In addition, a number of basic petrochemical products are often produced in refineries (aromatics), and the pricing and imports of these as well as feedstocks may be controlled by the refining subsector. For instance, in India, imports of naphtha and aromatics are canalized through the Indian Oil Corporation and their pricing is established by the Government's Oil Coordination Committee, using complex formulas providing guaranteed returns on equity for refineries as well as tax income for the federal budget. Resulting prices are high, as detailed earlier. Imports of naphtha and LPG are also controlled in Indonesia, which is a net exporter of both commodities. In Thailand, imports and pricing of all potential feedstocks (including naphtha, LPG, natural gasoline and condensates) are controlled by PTT, the Petroleum Authority of Thailand. In Malaysia and South Korea, however, imports of naphtha are not subject to licensing requirements.

Import licensing for feedstock may constitute a disincentive to olefin and aromatic production, particularly if production is based in part or totally on feedstocks other than natural gas (LPG, naphtha or heavier), and if the domestic availability of these is insufficient to cover domestic demand in other uses. The domestic demand for gasoline is particularly important as it may constrain the availability of naphtha from domestic refineries for olefin and aromatic production. As discussed in Chapter 2, there has been a trend in the world to build olefin crackers with flexibility to use a variety of feedstocks in order to lessen dependence on a single feedstock (naphtha) and be able to take advantage of opportunities on world markets offered by changes in relative prices of a range of possible feedstocks (naphtha, LPG, gas oil, condensates, etc.). Flexibility is also sought as a hedge against fluctuations in availability of materials in the international market. This is particularly critical for plants which are dependent on external supplies.

The decision to free imports of naphtha in Korea (with very low import duties) stems from such a need. In countries which cannot supply their industry with all its feedstock requirements, or at competitive cost with any potential alternative feedstocks, the petrochemical industry would greatly benefit from free access to a range of imported feedstocks, even if this runs against existing monopolies on the import and distribution of refinery products.

Protection

The wide range of nominal and effective protection rates prevailing in the six countries under study reflects to some extent differing stages of development of their respective petrochemical and downstream user industries. Tables 5.3 and 5.4 show the structure of nominal and effective protection for key products in 1988. The effective protection shown is theoretical, to the extent that it is based on the prevailing tariffs. Realized protection may be lower if actual producer prices are lower than those afforded by the tariffs.2/ However, in the medium and long term, the tariff structure is a key determinant of the industrial structure in the subsector.

Nominal Protection. With respect to nominal protection, low rates prevailing in Malaysia and Indonesia essentially reflect the incipient stage of the industry, where production is limited to a few plants at the processing end (typically, PVC from imported VCM and polystyrene from imported styrene). In these countries, imports are not competing with domestic producers and tariffs are maintained at low levels (0-5%), except for those few products which are being produced domestically, for which higher tariffs of 10-35% apply.

The tariff structure in Thailand and China is more indicative of countries where the petrochemical industry is relatively new but already fairly diversified, with production already extending upwards into intermediates and basic petrochemicals. Import substitution has been and still is the major motivation behind the development of the industry. Duties on basic materials and intermediates, though relatively high, remain lower than on resins, fibers and rubbers, which provides higher effective protection to downstream users.

India has developed its petrochemical industry under high tariffs throughout the vertical chain. Self sufficiency has been the primary goal, and high tariff protection has combined with other import restrictions to in fact prohibit competing imports. However, plastics, the production of which is relatively new in India, have had a more liberal trade regime and lower tariffs since 1986. (Tariff duties on plastic polymers have decreased significantly, from a 90-200% range in 1985 to a 30-65% range in 1988.)

2/ Consistent information on domestic ex-factory prices is not available to estimate "realized" effective protection coefficients.

At the other end of the spectrum is Korea. Development started in Korea in the early seventies under moderate to relatively high protective barriers (40% on average). As the industry matured and developed, the Government has progressively lowered the level of protection, in order not to jeopardize the export competitiveness of the user industries (automobile, electronics, capital goods, textiles and clothing, and other manufacturing industries). In 1988, the Government announced its intention to further reduce duty rates over a 5-year program to no more than 2-8% by the end of 1993.

The importance given to indirect exporting industries has varied with: (a) the size of the domestic market; (b) the degree of saturation of the domestic market; and (c) the importance of manufacturing exports in the economy. Statistical information on the share of exporting industries in the use of petrochemicals is scarce. However, in Malaysia, it is estimated that 70% of domestic production of PS and PVC and 20% of all polymers used is being indirectly re-exported already. The share of petrochemical materials in the cost of exported items greatly varies with the complexity of the products and value added.

With respect to the dispersion of tariffs, there is reasonable consistency in China, Thailand and Korea between products as well as categories of products. This is not the case in the other countries. Indonesia and Malaysia have started granting differentiated protection to particular products when domestic producers have initiated production (PVC, PS and some synthetic fibers and yarns). The products on which tariffs are low are those which are not produced domestically. The impact on the tariff structure of an uncoordinated, unplanned, case by case approach is exemplified by India and Indonesia. In India, these policies have resulted in a wide dispersion of tariffs between categories of products and between products in the same category. In Indonesia, the protection afforded to PVC and PS is already resulting in the construction of intermediate plants (VCM and Styrene monomers) from <u>imported</u> merchant ethylene, which are unlikely to be economic in the long run (part of the VCM production is to be exported).

<u>Effective Protection</u>. As shown in Tables 5.3 and 5.4, tariff differentials between basic petrochemicals, intermediates and finished products are the major determinants of effective protection rates (EPRs). Malaysia and Indonesia have generally the lowest EPRs because most inputs and outputs have little protection. In these two countries, EPRs generally range from 0% to 5%, except for a limited number of products produced domestically: VCM, PS, PVC, PSF and SBR in Indonesia, for which EPRs range from 15% (VCM) to 117% (PS); and styrene, PS, PVC and nylon yarns in Malaysia, for which EPRs range from 11% (styrene) to 131% (PS).

China and Thailand show a more consistent pattern of effective protection, although it still remains dispersed: in China, EPRs are generally between 20% and 40% for basic chemicals and intermediates (there are some instances of negative rates such as DMT and PTA). For plastics, fibers and rubbers, EPRs generally range between 30% and 90%, although there are also some instances of negative rates (ABS). In Thailand, EPRs on basic chemicals

Table 5.3: NOMINAL PROTECTION RATES
RATES OF IMPORT DUTIES, 1988
(% CIF)

	India	Indo-nesia	China /a	Malaysia	Thai-land	Korea 1988	Korea 1993
Feedstocks							
Naphtha		5				2	2
Basic petro-chemicals							
Ethylene	406	0	20-30	2	20	10	5
Propylene	544	0	20-30	2	20	10	5
Butadiene	670	0	20-30	12	20	10	5
Benzene	--	0	15-20	35	20	10	5
Toluene	--	0	20-30	2	20	10	5
Paraxylene	115	0	15-20	2	20	10	5
Ammonia	110	5	25-35	2	20	10	2
Methanol	120	10	20-30	0	20	10	5
Intermediates							
Cyclohexane	512	0	20-30	2	20	10	5
Caprolactam	72	0	25-35	2	20	15	8
Styrene	72	0	25-35	2	20	15	8
EDC	n.a.	5	20-30	2	20	20	8
VCM	14	0	20-30	2	20	20	8
Ethylene glycol	148	0	20-30	2	20	15	2
Acrylonitrile	110	5	20-30	2	7	15	8
DMT	210	0	20-30	2	20	15	8
PTA	208	0	20-30	2	20	15	8
Plastics							
HDPE	54	5	35-45	2	40	20	8
LDPE/LLDPE	54	5	35-45	2	40	20	8
PVC	42	30	35-45	25	40	20	8
PP	48	0	35-45	2	40	20	8
PS	48	30	35-45	35	40	20	8
ABS	n.a.	5	n.a.	2	40	20	8
Fibers							
Polyester staple fiber	213	15	25-35	5	n.a.	20	8
Nylon 6 filament yarn	124	30	60-80	2-15	n.a.	20	8
Acrylic staple fiber	180	0	25-35	2-15	n.a.	20	8
Rubbers							
SBR	100	5	25-35	0	25	20	8
PBR	100	5	25-35	0	60	20	8

/a Minimum and general rates.

Table 5.4: THEORETICAL EFFECTIVE PROTECTION RATES /a

	India	Indo-nesia	China	Malaysia	Thai-land	Korea 1988	Korea 1993
Ethylene (merchant)	440	0	27	2	16	11	5
Styrene (A)	-14	0	30	-10	20	29	11
(B)(1)	93	0	34	11	21	24	9
(2)	98	0	--	11	17	--	--
VCM (A) from EDC	30	15		-5	11	11	5
(B)(1)	1	0	41	2	24	23	9
(2)	7	0	41	2	24	23	9
DMT	355	-2	-17	2	17	18	10
PTA	318	0	-11	2	17	17	9
Caprolactam	77	-1	30	2	19	16	9
Acrylonitrile	-445	11	26	2	-9	23	13
Plastics							
Polyethylenes (A)	-540 to -860	14 to 19	71 to 88	2	22 to 94	39 to 50	14 to 17
(B)(1)	40	5	53	2	42	21	8
(2)	49	5	--	2	34	--	--
PP	-480	0	53	2	56	28	11
PS	-28	117	80	131	97	18	7
PVC	75	66	62	53	65	22	9
ABS	-140	12	-42	-2	80	28	10
Fibers							
PSF	227	29	57	8	59	25	8
NFY	198	0	27	16	68	27	8
Rubbers							
SBR	-166	9	35	-6	29	25	10

/a Theoretical protection afforded by the tariff structure. Actual protection may be lower if actual prices are below the maximum levels permitted by tariff duties.

(A): From merchant ethylene.
(B): Integrated with ethylene production.
  (1): Ethylene from naphtha.
  (2): Ethylene from ethane.

and intermediates are lower than in China and the range is narrower, 15% to 25%; however, EPRs for finished products are equally dispersed between 30% and 90%. The dispersion of nominal protection in India has resulted in a structure of widely different EPRs of extreme values, positive as well as negative, with no consistent pattern across products and product types. Keeping in mind the qualifications made below, namely, that these estimates are based on maximum prices afforded by the tariff structure (not actual ex-factory prices) in a particular year, the existing structure appeared to be highly favorable to certain types of intermediates (merchant ethylene, styrene, DMT and PTA, caprolactam), highly unfavorable to others (acrylonitrile) or neutral (VCM). With respect to finished products, the structure was also highly favorable to fibers, highly unfavorable to rubbers (SBR) and favorable to plastics only as long as their production is integrated with ethylene production. Korea is the country which exhibits the most consistent structure of EPRs. In 1988, EPRs on intermediates and basic chemicals were in a range of 10-30%, mostly around 20%. Finished products had EPRs ranging between 18% and 50%, mostly between 20% and 30%. When new tariffs are in effect in 1993, all EPRs will be below 20%, most of them between 5% and 15%.

The interpretation of the above results requires some caution. Realized EPRs can be different from theoretical EPRs derived from tariff levels. Producer prices may be substantially lower than CIF plus duties if substantial domestic competition exists; if there is excess capacity over demand internally; if purchasing power limits the growth of demand, particularly when international prices are increasing very fast, as was the case in 1987/88; or, when domestic indirect taxation raises prices to levels which make final products uncompetitive with substitute products. A good example of such occurrences can be found in India, as shown in Table 5.5.

Table 5.5: ESTIMATED EFFECTIVE PROTECTION RATES IN INDIA, 1988

	Theoretical	Realized
Major Plastics	40-60%	0-20%
Intermediates for Fibers	100-350%	30-140%
Fibers	above 170%	above 90%

Other factors which mitigate the impact of tariffs are the various schemes of duty exemptions or refunds applicable to indirect exporters (exporters of products using petrochemical materials as inputs). In Malaysia, for example, domestic producers of PS and PVC derive substantially less benefits from the protection on their products than indicated by the duty rates (30-35%): 70% of their output is sold at international prices to customers located in Free Trade Zones and Licensed International Warehouses (these are free to import their raw materials free of duties). The balance of sales are in smaller lots sold to other indirect exporters located outside these areas, at prices 8-12% above CIF prices, and to domestic users, at prices only 12-18% above CIF levels. Much lower tariff duties levied on competing plastic materials are thus preventing domestic producers of PVC and PS from taking much advantage of protection granted, even with clients not benefitting from import duty exemptions.

Finally, high tariff protection granted to merchant olefins (in particular ethylene and propylene) may not be very meaningful because: (a) natural protection derived from the difficulty and the cost of transporting and storing these materials is so high that imports of merchant ethylene and (to a lesser extent) propylene are rarely in a position to compete with even high cost domestic materials; and (b) for that reason, the incentive to integrate olefin production with the first stage of processing (such as PE granules or VCM or styrene) is so large that it is the protection on these products (which are much more easily transported and stored) which will in fact determine the actual (realized) level of protection on olefin production. The effective protection rates calculated for India separately on ethylene production and polyethylene or styrene shows extremely high EPRs for ethylene production and very negative EPRs for polyethylene and styrene because of the extremely high tariff on merchant ethylene (Table 5.6). If, however, the production of these downstream products is integrated with ethylene production, as is normally the case, EPRs on integrated production of polyethylene and styrene become positive. Thus, the relevant tariffs are those on the products of the first processing stages (polyethylene, styrene, VCM, ethylene glycol) because, although there may be temporary reliance on imports of merchant ethylene by downstream plants built ahead of the associated crackers, permanent reliance on imported ethylene is generally not economic even in the absence of tariffs on ethylene.

Impact of Protection. There are indications that high rates of effective protection are not conducive to efficiency and optimal plant location and sizes, in particular, high EPRs provide less incentives to take advantage of economies of scale and to retire old, obsolescent plants. A comparison of India and Korea, where the development of the industry started at about the same time (late sixties, early seventies), but which are at the two extremes of the EPR range exemplifies this point. As shown in Tables 5.7 and 5.8, the average capacity of plants in operation and under construction in India is consistently lower than in the other five countries, and very significantly lower than in Korea. Finally, the dispersion of EPRs across products horizontally and vertically is also likely to have biased investment decisions in favor of the most heavily protected materials (for instance, in India, in favor of PVC against PS).

Table 5.6: EFFECTIVE PROTECTION RATES, 1988

(%)

	India	Thailand	Korea	Malaysia	Indonesia	China
Ethylene (merchant)	440	16	11	2	0	27
VCM, integrated w/ethylene	1-7	24	23	2	0	41
EDC	n.a.	35	22	-2	8	16
VCM, from EDC	30	11	11	-5	15	-13
PVC	75	65	22	53	66	62
Styrene, integrated w/ethylene	95	19	24	11	0	34
Styrene, from merchant ethylene	-14	20	29	-10	0	30
PS	-28	65	22	131	117	80
Ethylene Glycol	-840	-11	3	-1	0	12
DMT/PTA	318-355	17	17	2	0	-11-17
PSF	227	59	25	8	29	57

Source: Staff estimates.

Capacity Licensing

All six countries under study require new investments in the sector to be approved by the government before they can proceed. In all cases, capacity licensing has been used as a primary tool to shape the ownership structure of the industry and its integration pattern, with the objectives of (a) achieving maximum national ownership and control of production capacity, and (b) avoiding concentration of such capacity in the hands of one or very few private investors. These policies have invariably led to a significant share of public ownership and lack of integration. An analysis of issues associated with the ownership structure of the industry is presented in Chapter 6. Licensing regulations are used for different purposes and approvals are granted more or less liberally according to countries. In India, and to a lesser extent in Indonesia and Thailand, licensing is used to attempt to match supply to projected demand; as a tool to balance public and private ownership; and as a means of avoiding excessive concentration of ownership.

Table 5.7: AVERAGE CAPACITY OF PLANTS IN OPERATION
(tpy)

	India	China	Thailand	Korea	Indonesia	Malaysia
Ethylene	54,000	103,000	--	250,000	--	--
Butadiene	--	n.a.	--	47,000	--	--
Benzene	22,250	n.a.	--	85,000	--	--
Methanol	--	194,000	--	330,000	330,000	660,000
VCM	29,000			60,000		
Styrene	30,000			95,000		
LDPE/LLDPE	36,000	80,400	87,000	135,000	--	--
HDPE	50,000	87,500	--	93,000		
PP	30,000	33,000	--	170,000	10,000	--
PS	7,300	4,500	23,000	70,000	20,600	15,000
PVC	24,300	80,000	54,000	180,000	47,000	19,500
ABS	2,000	10,000	--	63,000	--	--
Ethylene glycol (EG)	24,500			80,000		
DMT	48,000			--		
TPA	100,000			500,000		
Caprolactam	20,000			40,000		
Polyester sta.	6,700	73,000	19,200	30,300	17,600	40,800
SBR	33,000	50,200	--	75,000	--	--

Source: ASTIF Petrochemical Data Base.

Experience in India, however, has shown that capacity licensing in the sector has generally had adverse effects because: (a) investors have interpreted the granting of a license as a protection against oversupply, and have thus tended to rely heavily on the Government's ability to project domestic demand without developing independent market estimates; (b) licensing has tended to enhance existing protection of established producers who have also organized themselves to lobby against the granting of licenses to new entrants; (c) consequently, the granting of new licenses has normally lagged behind demand, existing producers have tended to operate in a sellers' market with little incentive to innovate, improve efficiency or stop uneconomic operations; and (d) there has been little incentive to develop export markets or meet the needs of export segments among users since the domestic market has always been able to absorb comfortably all available production. Only in the case of India, where distortions from high protection and regional incentives offered are so high, can a capacity licensing system ensuring minimum scales be justified.

Table 5.8: AVERAGE CAPACITY OF PLANTS UNDER CONSTRUCTION
(tpy)

	India	China	Thailand	Korea	Indonesia	Malaysia
Ethylene	300,000	210,000	315,000	340,000	--	--
Butadiene	--	n.a.	--	54,000	--	--
Benzene	--	n.a.	--	65,000	123,000	--
Methanol	100,000	--	--	--	--	--
VCM	--	--	--	150,000	--	--
Styrene	--	--	--	--	--	--
LDPE/LLDPE	75,000	125,000	70,000	100,500	--	--
HDPE	62,000	--	77,000	80,000	210,000	--
PP	53,000	40,000	85,000	77,000	128,000	--
PVC	00	25,000	135,000	70,000	70,000	--
ABS	5,000	--	10,000	26,000	4,500	--
Ethylene glycol (EG)	--	--	--	--	--	--
DMT	--	--	--	100,000	--	--
TPA	--	--	--	153,000	--	--
Caprolactam	--	--	--	40,000	--	--
Polyester sta.	20,000	18,000	--	200,300	120,000	--
SBR	--	--	--	16,000	25,000	--

Source: ASTIF Petrochemical Data Base.

It is in response to these adverse effects and to restrictions on domestic competition that some countries have started experimenting with more liberal licensing policies. In Malaysia, requests for new licenses are now being granted much more liberally. Korea has gone the farthest by having liberalized its licensing policies in the past few years. Licenses are now being granted quasi automatically, and licensing requirements will be altogether eliminated starting 1990. These policies have shifted the responsibility for proper market assessment to the investor and are leading to higher efficiency through better assessment of competitive advantage and competition for market shares.

While the elimination of capacity licensing encourages domestic competition, it is not sufficient to achieve an optimal industry structure, particularly when the domestic industry operates under high trade barriers. The example of the synthetic fiber industry in India is illustrative in this respect. In the early 1980s, the Government decided to promote domestic competition in polyester fiber manufacture by liberally granting new licenses, but without lowering tariffs, removing the import restrictions, or lowering the very high excise taxes which constrained faster growth in demand. The result was a multiplication of small sized new plants which today operate below capacity. Since then, the Indian Government has established minimum sizes for new plants when there are important economies of scale, in order to obtain a license. Minimum scale criteria have also been used in China since 1978 in the planning of new complexes at the national level. Since the penalties for not achieving the economies of scale associated with international sizes of plants are so high in the petrochemical sector, this may be a justified policy, particularly in a transition period of gradual lowering of protection.

Investment Incentives

Many countries have used special investment incentives to assist in the development of their petrochemical industry. These incentives have been established in order to attract foreign and domestic investors to compensate for the following penalties: (a) the degree of uncertainty on the direction of international markets and the rate at which the domestic market can grow; (b) the lack of supporting infrastructure (ports, transports, utilities, telecommunications); (c) various policy-related factors and, state interventions in feedstock allocation and pricing; and (d) high capital costs due to less efficient implementation, restrictions on the use of foreign equipment and taxation on capital goods.

Most of the incentives offered attempt to compensate for these penalties. These include (a) exemption of corporate tax for several years after plant commissioning, (b) duty-free imports, (c) investment tax allowances, (d) accelerated depreciation schedules, (e) the provision of infrastructure, and, for foreign partners, allowances in the repatriation of capital and dividends, concessional credit facilities, and even special tariff protection. The tendency however has been to reduce them progressively as the industry develops.

In Malaysia, the petrochemical industry is among the sectors that benefit from the Pioneer status defined under the Promotion of Investment Act of 1986. Under these regulations, new plants enjoy an exemption of corporate taxes for five years after the start of commissioning, with a possible further extension to ten years. Other incentives include accelerated depreciation schemes and the exemption of tariffs on imported machinery. If the industry is export oriented and located in either a Free Trade Zone or a Licensed Manufacturing Warehouse, it will benefit also from full duty exemption on imported raw materials. Finally, under the foreign equity guidelines, foreign ownership is allowed for up to 100% of equity if the industry is export oriented, i.e, exports at least 80% of its output.

The Malaysian regulations are transparent and have a degree of automaticity which is attractive to potential investors and leave relatively little to discretionary approvals or denials. Special tariff protection, although a possibility in the regulations, cannot however be granted by the agency in charge of formal approval of incentives; this limits the possibility of using protection as a promotional tool. The Malaysian regulations are essentially geared to promoting export industries, which, given the small size of the internal market, would be the case of a petrochemical industry.

Thailand also has designed a set of similar privileges applicable to the industry under the Investment Promotion Act of 1977 (which was revised in 1987). The set of incentives include corporate tax exemptions or reduction from three to eight years; as well as accelerated depreciation allowances, investment tax credits and exemptions from duties on imported equipment. For export oriented enterprises, the incentives include: duty exemption or reductions on imported raw materials. Incentives are granted by the Board of Investment (BOI). Until 1987, the administration of incentives was criticized for being too discretionary and that the various exemptions were handled too much on a case by case basis. The 1987 revisions have streamlined these procedures and made them more automatic and uniform for similar investments. BOI is also responsible for licensing of capacity and has considerable flexibility in determining the magnitude of foreign equity shares (in that respect, Thai regulations are not very restrictive; although regulations specify that production for the domestic market requires a majority domestic equity).

Investors who participated in the first petrochemical complex in Thailand were able to receive generous incentives. The granting of incentives for the second complex now under planning is presently under review, but it is likely that, given the stage of development of the infrastructure and the experience gained during the implementation of the first complex, these will be less generous. The current controversy about these incentives also stems from the fact that petrochemical production is essentially geared to the domestic market and that large incentives are already available to the industry in the form of high effective protection rates.

The evolution of incentive policies in Korea provides an insight on links with overall changes in the development strategy for the subsector. In the 1970s conglomerate participation was encouraged through financing at concessional terms, protection from imports, provision of infrastructure and government financing in the production of basic petrochemicals. A range of other incentives was also available in the form of tax exemptions for foreign investors, as well as duty exemptions on imported machinery. Corporate tax exemptions however have not been available since 1979 and duty exemptions on imported machinery (the current duty rate is 15%) are now exceptional. Also, the level of tariff protection is being reduced. Finally, it has been recognized that the generous concessional credit allocated by the Government, at what were negative real interest rates, has had serious adverse effects on the petrochemical industry.

In India, there are no special incentives applicable to the existing industry and the corporate tax rate is the highest among the six countries (52.5% versus 35% to 40%). There are five-year exemptions in the country's two free trade zones, but these are congested and infrastructure and services are poor. In the so-called backward areas, there is a series of further exemptions and concessional loans which would require further analysis to assess their potential impact on location decisions in the industry. There are some restrictions on foreign ownership, but capacity licensors in the industry favor domestic owners in the allocation of licenses.

In China, special incentives are offered for joint ventures with foreign partners, and for investments (which may be wholly owned by foreigners) in the country's 4 Special Economic Zones (SEZs) and its 14 Coastal Port Cities. In all above cases, there are reductions in income taxes (the applicable rate is only 15%) and there are additional exemptions on reinvested profits. Joint ventures benefit from a two-year income tax exemption. All producers benefit from an exemption of duties on imported capital goods and imported raw materials. SINOPEC has been making extensive use of these benefits. Of SINOPEC's enterprises, 9 are located in SEZs or open coastal cities, and SINOPEC's subsidiaries have set up at least 20 joint ventures with foreign business partners for the production and sale of plastic products, detergents and wax products.

Finally, Indonesia presents a somewhat similar situation to India in that there are no special tax incentives, except for duty exemptions on capital goods and raw materials (up to two years for raw materials) in the two existing custom-free and bonded export processing zones (also congested and with inadequate infrastructure). In addition to the practice of using capacity licensing to privilege domestic owners, there are serious restrictions on foreign ownership: foreign investment can only be in the form of joint ventures and the share of domestic equity must increase from a minimum of 20% at the start to at least 50% after 10 years.

In summary, experience has indicated that incentives have been required in Thailand and Korea to initiate development and to offset the impact of distortions in the economy, particularly when the user industry is directly or indirectly export oriented. However, as soon as the country has established its ability to implement projects efficiently, supply the required raw materials at fair prices and provide the necessary infrastructure, such incentives are generally no longer required and investment decisions could be governed essentially by competitive advantage, particularly in this industry, which is global in nature and where mistakes are expensive. If granting of special privileges cannot be avoided (to counteract similar privileges in other countries in the region), it is important that (a) the system be transparent and with a fair degree of automaticity, and (b) special tariff protection should not be part of the special privileges which can be granted by the capacity licensing institution.

Finally, one aspect which would deserve closer analysis would be the extent to which the various domestic regulations hinder equity participation in joint ventures abroad, including by state-owned companies. This is relevant because of the large differences in feedstock costs. It might be advantageous for some countries to invest abroad in countries with cheaper sources of raw materials or with a well developed infrastructure, in exchange for a take-off agreement for part of the output (and of course sharing of dividends). China, Taiwan and Korea are already contemplating this approach in their search for cheap sources of basic and intermediate petrochemicals.

VI. FUTURE DEVELOPMENT OF THE INDUSTRY

In this chapter the future of the industry is examined from three different angles: (a) the issues and obstacles facing its development (summarized in Table 6.1), (b) a projection of markets and diagnosis of the demand supply situation by 1995, and (c) a review of strategies to face the challenges of the next decade.

Table 6.1: ISSUES AND CONCERNS AFFECTING THE PETROCHEMICAL INDUSTRY

	Korea	India	China	Thailand	Malaysia	Indonesia
Feedstock	X	X	X	X		X
Overcapacity	X	X		X		
Competitiveness	X	X	X			
Market size				X	X	
Rationalization		X	X			
Financing		X	X			X
Environment	X	X	X	X	X	X
Industrial policy		X	X	X	X	X

Issues Affecting Future Development

Overcapacity

Most countries in the region have ambitious expansion plans involving substantial increases in capacity. With a few exceptions, the domestic markets are expected to absorb the plants under construction. On the other hand, the materialization of all projects under planning in the time frame being considered may create a problem of overcapacity in some countries in Asia by the mid-1990s, although the region is expected to remain a net importer as a whole. The situation is particularly delicate in South Korea, where 2 million tons of ethylene and 3 million tons of resins are under planning. The domestic market will not be able to bear all these additions. A potential problem also exists in India, with a large number of projects being considered and in Thailand where the new capacity will exceed the size of the domestic market's needs and exports would be required. In the case of India, although the GOI has an optimistic market projection that has further enticed potential investors, the implementation of all proposed projects is not likely to proceed in the proposed timetable. Thus, the probability of a surplus in India is not high. In these cases the eagerness of the private sector to step into growing markets and perceived attractive margins has been aided by the lifting of restrictions to licensing (Korea), encouragement to increased private ownership of new capacity (India, Thailand), as well as high protection levels (India). The problem is compounded by the fact that investments take 3-4 years to materialize into producing units while in the meantime the cycles of the market may drastically change its outlook.

Overcapacity is not an issue for now in China and Indonesia where the market requirements are well ahead of new investments (China) or expansion programs are still undefined (Indonesia), but these countries will also be indirectly affected through the impact, on the regional market, of excess supply in some Asian countries. To overcome the perils of overcapacity in an environment of gradually decreasing control, the industry needs to improve long term planning and learn from the disastrous consequences caused by excess supply in industrialized countries in the past.

Environmental Concerns

Environmental concerns have become very important in the US and Western Europe. This is also a major issue regarding existing and future Asian-based producers, as exemplified by the Indian government reaction to the Bhopal disaster and the enactment of stringent environmental legislation in India, Indonesia, Korea, Japan and Taiwan. In India, for example, the chemical industry has been identified as one of five major industrial polluters in the country. This means that future plants will have to go through a careful screening at design and before start-up is allowed. Since most existing plants are located in densely populated areas, one may also expect further environmental legislation, and tougher enforcement of environmental standards.

In Taiwan and Korea, the location of new complexes has become a public issue because of the perceived aggregated impacts of new capacities on existing industrial parks. Although the example of Taiwan, where a local producer sought an overseas location when denied a license to locate on environmental grounds, may not be repeated in other countries, the fact is that new plants are faced with a more stringent set of standards and increased environmental awareness. The industry must quickly adapt and accept the limitations posed. Quick adoption of new standards and compliance with emission performance guidelines is essential for the healthy growth of the industry. This is an area that requires strong governmental attention and awareness by management and owners. Compliance requires the allocation of resources for training, and monitoring, a strong regulatory body and the levying of financial penalties commensurate with the social and economic costs of pollution.

The issue of solid waste disposal has not surfaced in Asia to the extent that it has in the US and Western Europe, in part because disposables are a smaller fraction of plastic end uses and also due to higher rates of recycling. But it will be in the long term benefit of Asian producers to incorporate quickly the lesson learned in industrial countries regarding recycling, reuse and incineration. In Asia, the potential impact of this fast growing industry on air and water quality and the long-term effects of pollution require firm action from investors, planners and regulators. If the industry is allowed to operate without the proper monitoring and control, the accumulated impact will eventually degrade the surroundings to levels unacceptable to society. Industrial waste treatment must be promptly implemented to avoid social and economic costs.

Large petrochemical installations are relatively amenable to proper environmental control since they are such significant investments that they can be carefully scrutinized at the planning stage and during operation. In addition they usually attract capable management that can be persuaded of the long term benefits to the company of being responsive to environmental concerns. A more intractable problem are the small scale operations that development of a basic petrochemicals industry promotes,which are much less visible than the large operations and are more concerned with short term profit considerations than environmental concerns. Second is the issue of incentives. Private companies have insufficient incentives to incorporate these processes on a purely economic basis. Therefore, incentives or legislation have to be introduced to initiate proper waste disposal. Also, given the high recycling as well as the low per capita consumption of plastics, the issue of solid residues is not likely to be treated with the same urgency being experienced in developed countries. Nevertheless, as illustrated by the experience in developed countries, early measures to handle solid waste properly will avoid serious environmental problems in the long run.

Financing

Considering the highly capital-intensive nature of the sector, financing the expansion of the industry appears to be an issue in some countries. In Korea, the large financial clout of the potential investors and the considerable progress made in financial sector liberalization have led to an unprecedented availability of resources for the sector. The complexes under construction and planning for the next five years will demand a total of US$7 billion equivalent, but financing does not seem to be a limitation. In China, financial constraints have slowed down the investment programs of Sinopec and forced innovative (by Chinese standards) approaches that contemplate the use of joint ventures with foreign companies and increased provincial government roles in financing. In Indonesia, financing has also surfaced as an obstacle to quick execution of the proposed olefins and aromatics centers, this time tied to the question of public sector involvement in the industry.

The implementation of large petrochemical complexes, which require large amounts of finance raise issues concerning not only the financial viability of the projects themselves but also the impact on the local financial systems. In determining the debt/equity ratios for these types of investments, competitive advantage and the vulnerability of the industry to fluctuations in international prices of inputs and outputs should be taken into account. A debt/equity ratio of 70/30 may be too high for export oriented industries, or design plants based on naphtha. In Chapter 5, mention was made of the large amounts of concessional foreign financing made available to Korean companies during the 1970s, which encouraged high leverage in financing their projects. The impact of this indebtedness (mostly in foreign currency) on the financial structure of the companies was disastrous when, as a result of the second oil crisis, naphtha prices increased sharply and the ensuing recession caused international prices of petrochemicals to collapse and capacity utilization to drop. Low margins and low capacity utilization caused serious difficulties for the companies and all sustained heavy losses.

Prudence in deciding on debt/equity ratios is also necessary because of the possible impact of such large financing needs on the domestic financial system. In Thailand, for example, it was not possible to obtain nonrecourse financing from abroad for the first complex. The domestic financial system eventually agreed to provide guarantees to international banks for the foreign portion of the borrowings, in addition to financing for the local portion, to achieve a debt/equity ratio of 75:25. This level of exposure of the domestic banking system in the sector makes it unlikely (and undesirable) for it to provide a similar financing package for the second complex. It is thus unlikely that nonrecourse financing can be raised from international financial markets unless investors propose a substantially lower debt/equity ratio to compensate for increased risk to the financial system. This in turn raises the issue of adequacy of domestic capital markets to raise the required levels of equity. It is often advantageous to keep open the option to attract foreign capital to complement the financial requirements for the industry and therefore diminish the large demands of the sector on the domestic capital markets.

Rationalization

A review of the scales of production in Asia reveals that over the last years most producers have progressively moved toward larger product capacities. Still, countries like India and China which started production many years ago are burdened by the operation of small and in some cases obsolete units. In Korea and Thailand, scale is now not an issue and in Indonesia and Malaysia the industry has yet to be established, but minimum sizes have already been imposed to potential investors. In the synthetic fibre and synthetic rubber industries, suboptimal scales are more widely spread within the region. The need for rationalization both physical and organizational has been recognized in both cases. The timing and sequence of the reforms required is much less clear.

Serious difficulties face the task of rationalization in a depressed economic setting. In such an environment excess capacity and low investment make structural changes more painful. The opportunity for rationalization is now supported by the generally bright outlook of the industry. This is in particular applicable to the textiles and rubber industries where new market opportunities for regional trade that may be opened by the renegotiation of the Multifiber Agreement (MFA) and the General Agreement on Tariffs and Trade (GATT) could only be fully developed if the local industries modernize in size, technology and productivity.

Integration and Ownership

With the exception of China where the industry has been centrally planned and is owned by the Government, the patterns of integration and ownership have been shaped by several factors: (a) the difficulty in securing equity financing by a single investor for the financing of integrated complexes, (b) government intervention in capacity licensing, and (c) in some cases, the reluctance of private investors to invest in basic petrochemical plants that rely on feedstocks provided through government agencies at costs fixed by the Government.

In Korea, Thailand and Taiwan, the governments intervened heavily in the initial phases of development of the industry, in particular through the financing and majority ownership of the ethylene plants, and the allocation of production licenses to as many as possible private investors in the associated downstream units. The progressive change in orientation with respect to integration and ownership in South Korea reveals the problems encountered with lack of integration. After a few years, the Government sold its shares in the ethylene plants to the private sector, but still insisted on the separation of ownership between upstream and downstream. Following the crisis in the industry in the early eighties, this last policy was changed and the Government is now officially encouraging integration. In China and India early integration was achieved through reliance on public sector monopolies that are now being exposed to greater competition from private investors or through licensing of integrated units to private parties (NOCIL and Reliance in India).

Government policies with respect to both ownership and integration, are progressively shifting towards more private (including foreign) involvement in the upstream plants, and better integration. In particular, it is being recognized that lack of integration is associated with a number of penalties:

(a) Fluctuations in international feedstock prices and product prices create uncertainty for petrochemical producers. Major producers, particularly those who do not benefit from market protection in their own countries, have reacted by integrating backward and forward as much as possible. Most of them have developed captive markets for their commodity products by incorporating them into higher value products. In this way, sales of petrochemicals are much less sensitive to prices and much more dependent on services and product differentiation associated with the final product.

(b) The establishment of transfer prices for olefins (which provides for a fair sharing of costs and benefits between producers and users) is difficult because of complicated and expensive transport.1/ Cost-

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1/ Producers in Texas and Louisiana in the US, and others in parts of Western Europe are linked through an ethylene pipeline that enables the purchase of merchant ethylene at low transport costs. In Asia, Thailand plus pricing formulas for ethylene which have prevailed in Korea and are under consideration in Thailand shift all the risks and benefits of widely fluctuating international prices for final products on downstream producers. Such formulas do not provide incentives to upstream producers (often the Government) to search for optimal feedstock composition. On the other hand, pricing olefins at their border price would in normal times artificially render the downstream industry uncompetitive because of the high cost of transport and storage of olefins.

Faced with these difficulties, countries have been searching for transfer pricing formulas simulating integration as much as possible. One alternative, is to link fluctuations in representative ethylene prices (not border prices) with fluctuations in downstream product prices, so that the risks and returns of downstream price fluctuations can be fairly shared. A basis for ethylene transfer could be the US Gulf contract prices, adjusted for cost advantages or disadvantages of ethylene production over production on the US Gulf Coast. Another way of reinforcing the sharing of returns could be a system of financial cross-participations of the upstream company into the downstream companies and conversely.

Illustrative of the difficulties encountered in such arrangements is the experience in Thailand and Korea. In Thailand, in the first olefin complex, the upstream cracker is owned and operated by the National Petrochemical Corporation (NPC), while the four downstream plants are owned by four different private investors. Forty-nine percent of NPC shares are publicly owned (by PTT, the Petroleum Authority of Thailand), 45% by the 4 downstreamers and the balance by the Crown Property Bureau and IFC. Transfer prices of olefins are established on the basis of the cracker's cash outflow (cash costs plus debt service) plus a 15% return on equity, which transfers all risks and benefits to downstreamers. While such a formula might be appropriate if downstreamers owned the cracker entirely, in the long term it may not be desirable for the major shareholder (the Government) to view cracking operations as utilities and just content itself with earning a relatively modest return on a major investment. While the intervention of PTT was based on the premises of providing the technical implementation expertise and the financial backing necessary for such a major investment, it might be desirable, once operations start, for PTT to transfer its share to downstreamers over a period of time.

In Korea, where the experience dates back to the early 1970s, the progressive changes in orientation with respect to integration and ownership reveal the problems encountered with a similar lack of integration. After a few years, the Government sold its shares in the upstream industry to

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has been an importer of small volumes of merchant ethylene. In India a private partner is considering an ethylene jetty for imports. Still, imports of ethylene are viable only under very specific conditions (low transport costs, large cargo volumes, high derivative prices).

the private sector, but still insisted on the separation of ownership between upstream and downstream. Following the crisis in the industry in the early 1980s, this last policy was changed and the Government is now officially encouraging integration of owners of upstream production into downstream operations and conversely.

Role of the Public Sector

The large public sector involvement, a trademark of the early stages of development of the petrochemical industry, is diminishing. In South Korea, the last public sector ownership was transferred to private hands in 1980. In other countries like Thailand and Indonesia, private partners have taken the lead from the start and in Malaysia, delays in awarding ownership can be traced to ambivalence regarding the potential role of Petronas. In Malaysia and Indonesia, however, the large public owned petroleum companies continue to argue in the face of increasing opposition for a dominant role at least in the supply of basic petrochemicals. Even in India a stronghold of public sector involvement, new investments are being awarded to private enterprises. Only in China is Sinopec still the undisputed leader in production and investments.

Concomitant with the expanded private role, industrial policy has generally moved toward an increased reliance on market signals and a reduction of direct intervention. Controls such as licensing, import restrictions and effective protection as discussed in Chapter 5 are being relaxed in an overall move toward a freer market environment, although there is a wide difference in pace of policy reform within the six countries. With less public sector involvement and the lessening of control mechanisms, the industry now faces the issue of disciplined capital spending, and disciplined market development, disciplined management. Cyclical business almost always overinvest during the period of high profits and thereafter regret it during the period of lean profits. The exercise of self restraint and control of expectations are new concepts for an industry that grew accustomed to license restrictions, controlled pricing and protection.

Trade Restrictions

Nontariff Barriers. The structure of manufacturing exports in the Asian countries, in particular Korea, Thailand, Malaysia and to a lesser extent Indonesia and China, make them vulnerable to changes in the trade environment and the establishment of nontariff barriers by developed countries. The concentration of exports on end-user products such as textiles, rubber manufactures, and others where nontrade barriers are on the rise, cloud the prospects for continuing strong performance of exports and trade.

To overcome this issue, the Asian countries have in their favor the following factors: (a) the trade linkages with Japan and the newly industrialized countries that can soften the impact of barriers established elsewhere; (b) the relatively advanced industrial infrastructure and management capabilities that can be used to diversify exports and increase competitiveness; (c) the structure of the petrochemical sector that offers the possibility of complementing further downstream sectors (such as assembly products, consumer appliances, electronics, and transportation equipment components), less susceptible to the establishment of trade barriers, and for which demand continues to be very strong.

Future Market Development

Market Forecasts. Projecting demand for petrochemicals is a difficult task, primarily because of the links of the sector with a large and heterogeneous group of economic activities, but also because the markets are very dynamic, with complexities related to product substitution, innovation and obsolescence. As an example consider the case of polypropylene a product first developed to make use of (at the time) a low cost by-product of ethylene cracking. Since first introduced, in the 1950s, polypropylene has found applications in agriculture (product bags), the textile sector (polypropylene base fibers), the construction industry (pipes, conduits), the automotive industry, high performance fiber and resins applications, disposables (substituting for polyethylene and polystyrene), consumer appliances and electronics, medical and health applications. The technical properties and specifications have changed many times and new and improved grades are introduced every year, every time changing its outlook and those of the products with which it competes.

Given the extensive use of petrochemicals in the economy of industrial countries, previous attempts to forecast demand for petrochemicals (McPike, 1986; UNIDO, 1985 for example) have invariably used GNP forecasts as a wide indicator of future demand. With some slight variations, the same procedure has been selected for purposes of this study. First, an indicator of industrial activity instead of GNP has been utilized. This in effect ties the forecast more closely to industrial activity instead of economic performance, an important difference given the early industrial stage of some countries in the sample. Second, linear and exponential regressions have been utilized depending on the country selected and using time series for individual countries. This allows differentiation between countries at an early development stage and those already experiencing market saturation. Third, a coefficient has been added to account for the effect of exogenous factors such as tariff barriers, limited production capacity, price to per capita income ratio and others. The equations used as well as the R^2 and t statistics are summarized in Annex 5.2/

In addition to a base projection based on the selected industrial indicators (Table 4.7), scenarios of low growth were also introduced. The low growth scenario reflects either a situation of recession in industrial activity timed to occur during the period 1991-93 or the effects of restricted

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2/ Prices for petrochemicals fluctuate in the international market, yet for purposes of this analysis it has been assumed that future demand will continue as in the past to show a strong relation (linear or exponential) with GDP growth.

supply of imports. The resulting forecasts for the six countries are summarized below. Specific product forecasts are included in Annex 7, figures 6.2 to 6.19.

Korea. The Korean market is at an intermediate point in terms of development. The per capita consumption of most petrochemicals is well above the average for developing countries in the area (Figure 6.1), yet, as discussed in Chapter 3, a big share of consumption is driven by exports and is therefore governed by factors well beyond the control of the Korean economy. The model selected as a basis to predict demand is linear, based on the high per capita demand. In addition, the relative difficulties caused by the increasing import resistance of traditional trade partners, in particular for synthetic fibers and rubbers subsectors, the competitiveness of new producers within the region, and the difficulties associated with feedstock availability were also taken into account for the selection of the linear model. Finally, a comparison was made between the resulting projections and those recently prepared by the Korean Institute of Economic and Engineering Studies (1988).

The results of the forecasts are summarized in Table 6.2. The scenario of low growth is also included. The individual projections for some chemicals are shown in Annex 7. The projections show an overall continuation of strong patterns of growth but at noticeably lower rates. If naphtha markets become tight and oil prices increase beyond what is expected, a significant reduction in competitiveness should result (see Chapter 4). This in turn will reduce the potential for Korean exports and further cut the expected market growth rates. A comparison of the forecasts with announced and planned capacities raises questions regarding the timing of the ambitious expansion program now taking effect and the viability of exports from the surplus capacities. Even if the GOK high-growth scenario is used, there is only market for two or possibly three additional cracking units by 1995. If more crackers are built (six are being promoted), the product would need to be directed toward the export market. But, as discussed in Chapter 4, the Korean producers are not likely to be cheaper than low cost producers outside of Asia or even potential low cost regional producers, such as Malaysia, in the export of polyolefins to the region. This surge of proposals is the result of the lifting of restrictions regarding the licensing capacity, the reaction of potential investors to the high margins available to producers in 1988 and the urge felt by existing producers to integrate. The projected supply/demand situation by 1995 accounting for projects under construction and projects under implementation is summarized in Table 6.3. Excess capacity is projected in olefins and synthetic resins if proposed plants are implemented.

India. Despite the size of the country, the established infrastructure, the recent investments in production capacity and progress in industrial policies, India remains at the lower scale within the Asia region, lowest among all countries in the analysis, in terms of per capita demand for petrochemicals (Chapter 3) and on the high side of production costs(Chapter 4). Also, and notwithstanding recent improvements, the country has one of the largest import resistances as measured by protection rates and trade barriers. These factors combined explain the relatively low stage and

Table 6.2: KOREA--DEMAND FORECAST FOR PETROCHEMICALS
('000 mt)

	1988	1990	1995 Base	1995 Low	GOK/a	Growth rate 1995/1988 Base	Growth rate 1995/1988 Low
Olefins							
Ethylene	1,332	1,686	2,522	2,228	2,603	9.5	7.6
Propylene	850	1,039	1,487	1,330		8.3	6.6
Butadiene							
Methanol	164	199	265	242		7.1	5.7
Benzene	337	382	664	503		10.2	8.2
Resins							
L/LLDPE	353	403	661	587	715	9.4	7.5
HDPE	306	374	649	570	723	11.4	9.3
PP	455	509	862	759	888	9.5	7.6
PVC	421	470	724	651		8.0	6.4
PS	299	350	650	564		11.7	9.5
ABS	125	138	250	217		10.4	8.2
Rubbers							
SBR	111	120	179	162		7.0	5.4
Fibers							
Total polyester	605	665	876	787		5.4	3.8

/a High case projection prepared by KIET, 1989.

Source: Staff estimates based on an econometric model tied to projected growth of the industrial sector.

inertia in the development of the industry. Future progress will depend largely on success in improving the competitiveness of the industry, through lower production costs and increases in productivity.

The forecasts for future demand are based on a linear model (supply restrictions, high import resistance, high costs, even though per capita demand is low) tied to expected industrial growth. No export markets were

Table 6.3: KOREA--PROJECTED 1995 DEMAND/SUPPLY SITUATION
(% of capacity in production)

	Demand/Supply	
	Including capacity under construction	Including proposed projects
Ethylene	168	72
Propylene	188	82
Methanol	80	80
Benzene	78	78
LDPE	98	81
HDPE	148	91
PP	105	71
PS	115	115
PVC	118	118
SBR	357	98
ABS	103	103
Polyester	155	155

Numbers over 100 mean insufficient capacity to meet demand. Current and projected installed capacities are summarized in Annex 6.

Source: Staff estimates.

considered. The results presented in Table 6.4 and Figures 6.7-6.10 are significantly lower than the Kapur report projections; but even at the rates shown in Table 6.4, the capacity under construction (Nagothane, Hazira, Rishra) will not meet the requirements of the domestic markets. In fact, additional capacity of 200,000 tpy of ethylene would be required by 1995 to meet all requirements. On the other hand, the projections do not appear to justify in the short term the large volume of proposed additions (a total of 1.8 additional million tons of ethylene capacity have been proposed with 0.5 earmarked for exports). Some of the units proposed are naphtha-based with capacities ranging from 50,000 to 250,000 tons per year which are very likely to be at a disadvantage vis a vis full scale plants based on natural gas and consequently prone to difficulties under stressed market conditions or right out not viable. The expected demand/supply situation by 1995 is summarized in Table 6.5. Overcapacity in olefins and some resins, will result if the projects under planning are executed, also given India, high cost structure, these projects will face tough difficulties in competing for export markets.

Table 6.4: INDIA--DEMAND FORECAST FOR PETROCHEMICALS
('000 MT)

			1990		1995/1988	
	1988	1990	Base	Low	Base	Low
Olefins						
Ethylene	608	707	1,022	918	7.7	6.0
Propylene	197	202	294	263	7.4	5.7
Benzene	190	231	319		7.7	
Resins						
L/LLDPE	145	170	250	217	7.5	5.9
HDPE	140	158	250	214	8.1	6.2
PP	65	79	132	114	10.6	8.4
PVC	220	237	357	317	7.2	5.4
PS	45	53	91	78	10.6	8.2
ABS	4	45	8	7	9.5	7.4
Rubbers						
SBR	30	34	47	43	7.0	5.0
Fibers						
Total polyester	46	222	529	459	13.2	10.9

Source: Staff estimates.

China. Because petrochemicals play such a central role in the Chinese industrial development program, there is very little doubt that the sector will continue to attract the attention of planners during the current modernization drive for the economy. This is also clear from the seventh five-year plan proposals for investment in the sector. For the entire seventh plan a total of US$7.5 billion has been projected for investments in the sector (EAER, 1988). The expansion in basic petrochemicals and derivatives requires that simultaneous efforts be taken to use and convert the products available. Major efforts are thus needed in beefing up the end-products industries such as plastic processors, synthetic fibers producers and rubber products manufacturers. This problem is being currently addressed by Sinopec as part of their planning process.

No forecast of domestic markets was available from Sinopec. The seventh economic plan calls for a 6% annual growth in the chemical industry to meet local requirements, but because imports are constrained through the

Table 6.5: INDIA--PROJECTED 1995 DEMAND/SUPPLY SITUATION
(% of capacity in production)

	Demand/Supply	
	Including capacity under construction	Including proposed projects
Ethylene	125	31
Propylene	136	67
Benzene	358	152
LDPE	120	81
HDPE	192	102
PP	53	80
PVC	138	140
PS	414	78
ABS	65	46
SBR	142	142

Numbers above 100 mean insufficient capacity to meet demand by 1995.

Source: Staff estimates.

availability of foreign currency, current consumption falls well below what would otherwise be expected. Therefore, the Chinese market has a very large unsatisfied potential demand as illustrated by the sizeable increase in imports of petrochemicals (particularly polymers) whenever restrictions are eased. Although the current per capita consumption is low, even modest increases would severely tax the ability of the domestic industry to meet the requirements. Additionally, as seen in the previous sections, feedstock supply raises concerns about the projected increases in production capacity. Because of this combination of factors and based on the historical pattern, a projection has been made for the petrochemical indicators, using a linear model. The results of the analysis are summarized in Table 6.6 and Annex 7. However, reliable statistical data were available for all products only up to 1986, and therefore miss the large market changes occurring during the last two years.

The results also imply that the total olefins and plastics market will about double in size by 1995. Even if financial conditions become a serious obstacle to growth and the domestic markets remain supply-restricted, the projections indicate that China will continue to dominate in total volume and level of imports the developing Asia petrochemical markets. If the base

Table 6.6: CHINA--DEMAND FORECAST FOR PETROCHEMICALS
('000 MT)

	1986	1990	1995 Base	1995 Low	Growth rate 1995/1986 Base (%)	Growth rate 1995/1986 Low (%)
Olefins						
Ethylene	1,417	2,200	3,400	2,825	12	9
Propylene	831	1,370	2,270	1,830	13	10
Butadiene	223	360	600	480	13	10
Methanol	524	780	1,230	1,010	11	9
Benzene	611	928	1,470	1,200	12	9
Resins						
PE	1,057	1,553	2,800	1,050	13	9
PP	487	835	1,390	1,230	13	12
PVC	630	867	1,300	1,170	9	8
PS	190	390	760	650	19	17
ABS	85					
Rubbers						
SBR	158	279	500	430	15	13
Fibers						
Total polyester	1,301	1,625	3,250	2,650	12	9

Source: Staff estimates.

case projections materialize, the additional capacities required for the olefins market amount to 0.8 million mty of ethylene and 0.6 million mty of propylene by 1995 over the projects already under construction. The 1995 supply/demand situation for China is summarized in Table 6.8.

Thailand. There is no doubt that the petrochemical industry in Thailand has entered a new stage, with world size production capacity benefitting from well planned and centralized infrastructure and a coordinated ownership arrangement. While NPC-1 is geared to meet the requirements of an already established and growing domestic market, future complexes are more likely to rely on a mix of exports and internal consumption. As has been the case in other countries where initial capacity has recently been set up, a

Table 6.7: CHINA--PROJECTED 1995 DEMAND/SUPPLY SITUATION
(% of capacity in production

	Demand/Supply	
	Including capacity under construction	Including proposed projects
Ethylene	128	112
Propylene	374	374
Butadiene	118	100
Methanol	195	195
Benzene	241	232
PE	321	--
PP	504	321
PS	726	726
SBR	177	177

Numbers above 100 mean insufficient capacity to meet demand by 1995.

Source: Staff estimates.

surge in domestic demand is expected in the short term as a response to NPC-1. Also, the prospect for domestic availability of aromatics and C4 olefins should result in an increase in the market size for styrenics and synthetic rubbers. The next stage represented by the second complex is a logical continuation of this well-planned process including the first aromatics plant and an expansion of the olefins capacity.

The GOT has prepared a market projection in the Petrochemical Master Plan. This projection is based on the assumption that domestic markets will grow at a faster rate than the historical trends due to the establishment of domestic producers and availability of local products. More recently, the Chem Systems/Bechtel team has produced a projection that in general terms has endorsed the earlier estimates by the GOT. For purposes of this study, the future demand has been projected, assuming an exponential model in the very short term to account for the impact of the first petrochemical complex (until 1992) and then shifting to a linear response to GNP growth. This conforms to the ratio of new capacity to market size when NPC-1 becomes operational, but also to the expected limiting factors related to available infrastructure for feedstocks and to the considerable regional competition for the export market. The results of the projections are presented in Table 6.8. Figures 6.13-6.18 show a comparison of the results of this study projections (generally lower) with those prepared by the GOT.

Table 6.8: THAILAND--DEMAND FORECAST FOR PETROCHEMICALS
('000 mt)

	1987	1988	1995 Base	1995 Low	Growth rate 1995/1987 Base (%)	Growth rate 1995/1987 Low (%)
Olefins						
Ethylene	205.6	296.3	471.9	408.8	10.9	8.9
Propylene	108.2	157.5	252.9	218.7	11.2	9.2
Butadiene	1.8	3.3	6.1	5.0	16.2	13.6
Methanol	20.7	70.4	33.4	28.6	6.2	4.1
Benzene	4.1	7.1	12.9	10.8	15.6	13.0
L/LLDPE	63.7	85.6	127.9	112.7	9.1	7.4
HDPE	82.3	124.6	204.5	175.7	12.1	9.9
PP	100.3	145.0	213.4	200.4	11.0	9.0
PVC	89.2	133.6	219.5	188.7	11.9	9.8
PS	34.5	49.4	78.3	67.9	10.8	8.8
ABS	2.6	4.3	7.2	6.1	13.7	11.5
SBR	5.9	7.9	11.7	10.3	9.0	7.3

Source:

An estimate has also been prepared of the exports volume required from the second complex per the different projections. If the base projection per the current study holds, then, close to 30% of all polyolefins from the second complex will need to be exported. The surplus production by 1995 has been estimated in Table 6.9. The actual tapping of import markets for this production is critical to the performance of the complex.

Malaysia. The petrochemical industry in Malaysia is in a stage of early development. Most of its short term future depends on decisions yet to be taken regarding the implementation of an olefins complex. Because of the size of the domestic market, a complex of this nature will have necessarily to rely on exports for most of its sales and therefore its prospects hinge on the ability to produce at competitive prices and on the size of the merchant markets for petrochemicals of the future. On the first count, and as discussed in Chapter 4, the prospects for competitive production of olefins and derivatives are quite favorable. But, on the regional market, a lot depends on the timing of the implementation. With investments already announced and in many cases with plants in construction for a large number of units in Asia, a future Malaysian complex will find a crowded market in the

Table 6.9: THAILAND--1995 DEMAND/SUPPLY SITUATION
(% of capacity in production)

	Demand/Supply	
	Including capacity under construction	Including proposed projects
Ethylene	149	83
Propylene	241	94
LDPE	32	P
HDPE	89	71
PP	118	63
PS	237	46
PVC	116	88
ABS	72	18

Numbers above 100 mean insufficient capacity to meet demand.

Source: Staff estimates.

mid-1990s, particularly for the type of product that would come out of a gas based olefins cracker where the country has a competitive edge.

The domestic market is growing fast but from a very small base. Exports of petrochemical derivatives are on the other hand a large fraction of total manufactured exports and Malaysia could also explore this route already followed by S. Korea and Taiwan. The Master Plan for the Petrochemical industry includes a forecast for growth of the market. For purposes of this study, a projection of future consumption has been prepared based on a linear model, based on the assumption that no local production capacity of basic materials will be available in the short term. The results are summarized in Table 6.10. Annex 7 shows the forecast for basic olefins, the results of the use of an exponential model, to reflect the impact of local availability of olefins and a conservative scenario based on a slow down of economic growth during the period 1991-1993. Still, none of the forecasts foresees the domestic market absorbing all the production of a large olefins plant.

Indonesia. Indonesia is among the countries that possess the domestic market and necessary feedstocks to develop a full-scale domestic petrochemical industry. It has also announced an ambitious program to develop its industry and provide the links between basic petrochemicals and derivatives, and therefore reduce the onus of expensive imports of synthetic resins and fibers that today penalize the local producers of end user manufacturers. But, despite the announcements and intentions, it is still not clear how and when the program will be crystallized. A number of issues, still awaiting solution, will strongly influence the outcome. These include: (a) feedstock availability, (b) financing arrangements, (c) location, and (iv) role of the government. While key decisions are pending, it is very difficult to say anything about the future of the industry. The markets though continue to develop, and a projection has been prepared based on a linear model of the future growth of the markets. The results are summarized in Table 6.11. The 1995 projected demand for olefins and resins by itself justifies the implementation of an olefins complex. The results also indicate that the aromatic projects under construction or planning will need to continue to rely on exports.

Table 6.10: MALAYSIA--DEMAND FORECAST FOR PETROCHEMICALS ('000 MT)

	1987	1990	1995 Base	1995 Low	Growth rate 1995/1987 Base (%)	Growth rate 1995/1987 Low (%)
Olefins						
Ethylene	124	191	375	311	15	8
Propylene	50	77	151	125	15	12
Butadiene	2	2	3	3	7	
Methanol	22	27	36	30	6	4
Benzene	18	39	81	63	21	16
Resins						
PE	104	162	302	266	14	12
PP	47	72	130	116	13	12
PVC	42	50	75	n.a.	8	n.a.

n.a.: Not available.

Industry Strategies

Feedstock. Countries like Korea and China which rely on heavy feedstocks or like Thailand and India with limited ethane/propane supplies have a lot to gain from feedstock diversification. This can be achieved either through building into new crackers the capability to process several feedstocks or as in the case of China by setting up facilities that would handle gas derived feedstocks such as ethane/propane or natural gas liquids. Diversification will soften the impact of higher costs or reduced availability of gas feedstocks but will increase the capital requirements and costs of production (Table 6.13).

Table 6.11: INDONESIA--DEMAND FORECAST FOR PETROCHEMICALS
('000 MT)

	1987	1990	1995 Base	1995 Low	Growth rate 1995/1987 Base	Growth rate 1995/1987 Low
Olefins						
Ethylene	272	300	417	378	5.5	4.2
Propylene	203	245	338	307	6.5	5.3
Butadiene	10	13	24	20	12.4	10.1
Methanol	278	369	670	570	11.6	9.4
Benzene	22	25	32	30	5.4	4.4
Resins						
PE	246	269	371	337	5.3	4.0
PP	193	233	321	292	6.6	5.3
PS	24	27	33	32	4.3	3.5
Rubbers						
SBR	13	18	32	29	12.4	10.1

Source: Staff estimates.

Table 6.12: INDONESIA--PROJECTED 1995 DEMAND/SUPPLY SITUATION
(% of capacity in production)

	Demand/Supply: Including capacity under construction	Demand/Supply: Including proposed projects
Ethylene	--	111
Methanol	203	203
Benzene	26	6
PP	81	62
PS	54	54
ABS	67	67
SBR	64	64

Numbers above 100 mean insufficient capacity to meet demand.

Source: Staff estimates.

Overcapacity. Reliance on market signals and a freer trade environment notably reduce overinvestment and excess capacity. But within a highly cyclical industry, investors will normally tend to invest in the good times. The industry needs to improve long-term planning. This is particularly critical when Government controls (licensing, production limits) are being lifted.

Competitiveness. The countries under study represent a wide gamut of competitiveness. Countries like Korea (Taiwan also) face in the short term a decrease in the competitiveness for the manufacture of olefine caused by expected higher costs of production, currency variations and increased competition from newer producers such as those being planned in Indonesia, Malaysia and others. Also nontariff barriers recently imposed on South Korea's production will mean a reduction in its ability to export textiles, garments, footwear and other end-user products that make use of petrochemical products. Other countries in the region may later face similar restrictions.

Japan's response to similar challenges is likely to be followed by Korea. Their strategy combines a series of measures, including: (a) efforts directed to improve quality and establish product differentiation to justify higher prices; (b) pursuing vertical integration to benefit from shared infrastructure and higher value added; and (c) selling both materials and services that would include support services tied to product sales, and specific industrial service needs. This strategy requires continuous innovation to sustain the competitive edge. But for some products, typically SBR and some commodity polymers, product differentiation opportunities may no longer be available.

A second group of countries, characterized by their relatively new entry into the market and/or abundant feedstock supplies (Malaysia, Indonesia) will need to opt for a low cost strategy. This strategy requires the realization of their potential as low cost producers. In other words, the ability to translate low cost feedstocks and low labor costs into low production costs. This will require of high standards in productivity, management and efficiency. The low cost strategy has an additional inherent advantage: these producers are less vulnerable to cycles and more likely to survive in the long run under stressed market conditions. A third group of countries (India and China, for example) are in an intermediate strategy position: these can not claim low cost advantages nor are yet in a position to provide product differentiation and quality advantages. In fact, countries in this group are not likely to compete in the regional market but rather to continue to develop an inward strategy while markets develop and experience is gained and to rely on imports to complement their domestic production.

Size of the Domestic Markets. The size of the domestic markets is an important issue for Thailand and Malaysia. Indirectly, it also surfaces as an issue in India and China where provincial markets are an important consideration in site selection. To bypass limitations on scale of production imposed by small domestic markets, low cost Asian based producers may explore the possibilities of agreements with net importing countries and/or maintaining themselves on a net importing status. Another way to deal with

Table 6.13: ASIA--COUNTRY INDUSTRY STRATEGIES

	Korea	India	China	Thailand	Malaysia	Indonesia
Feedstocks						
Diversify	X	X	X	X		
Increase reliance on natural gas fractions		X	X			
Overcapacity						
Improve planning and management	X	X		X		
Improve long-term response to market cycles	X	X		X		
Competitiveness						
Downstream integration	X		X			
Product differentiation	X					
Sell both materials and services	X					
Increase value added	X		X			
Realize market share through low-cost production					X	X
Market size						
Bilateral agreements with long-term import mkts				X	X	X
Reliance on imports until scales are achieved				X	X	
Rationalization						
Revamping of old and small plants		X	X			
Closure of noncompetitive units		X	X			
Financing						
Joint venture agreements			X			X
Trade-investment options			X			X
Environment						
Quick adoption and enforcement of emission standards	X	X	X	X	X	X
Industrial policy						
Effective protection		X				

market size limitations is to promote the creation of a more homogeneous market. For example, producers in Pacific Asia (Korea, Taiwan, Thailand, Indonesia, Malaysia) could adopt standard building, safety and environmental codes with the effect that producers of end user product components can more freely access larger markets based on competitiveness.

Environment

There is but only one valid strategy regarding environmental issues. The industry must comply with emission and performance standards and other limitations either through the adoption of modern waste treatment or minimization process, improvements in resource recovery or better plant housekeeping. The provision of incentives will accelerate compliance and can be part of efforts to maximize resource recovery, add value to by-products, improve energy efficiency and minimize waste.

Although the degree of treatment and protection is a function of local standards, the economics of resource recovery and the commonly industrial practices, no country can afford to ignore the long term effects of industrial pollution on the environment.

Summary

The prospects for future development of the industry in the six countries are generally positive. First of all, because the markets are expected to continue to grow and expand, soon converting the Asia region into a market of comparable size to other more developed regions. For example, the ethylene demand in the six countries is now more than 1.5 times the large Japanese demand. By 1995, demand for ethylene is expected to reach 10 mtpy for a yearly growth of over 10%. Plastics, fibers and rubbers are also poised to grow at similar rates. A second reason for optimism is the expected gradual evolution of the policy framework (pioneered by South Korea) toward a less restrictive environment, freer trade and lesser protection. Although the countries in the sample are all across a wide spectrum of policy, the trends clearly point, with some exceptions, toward a less regulated industry better linked to market signals.

A third reason is the differentiation of the markets in Asia that provide opportunities for mutual complementation. From the most sophisticated, highly integrated markets like South Korea to those with clear advantages as suppliers of polyolefins (Malaysia), the region is a showcase of the stages of market development in petrochemicals. The Asia producers have a lot to gain from this situation through complementary trade and markets. Finally, the abundant gas resources in the region in particular in Malaysia and Indonesia and the availability of other feedstocks, provide Asian producers with the possibility to become a long term low cost producer of basic petrochemicals and a competitive manufacturer of downstream products.

To secure their competitive position and materialize the growth prospects those countries in the region with the lowest competitive posture will benefit the most if corrective actions are taken now when prospects for progress are favorable. Priority actions for Korea and Thailand relate to diversifying and securing the feedstock base and continue vertical integration; for China and India restructuring of fibers and rubbers (India) is needed to improve competitiveness in those sectors; for Malaysia and Indonesia long term planning and long term export markets are required to develop its potential as low cost producers. In Indonesia improvements in production costs and vertical integration are needed to realize its advantageous feedstock position.

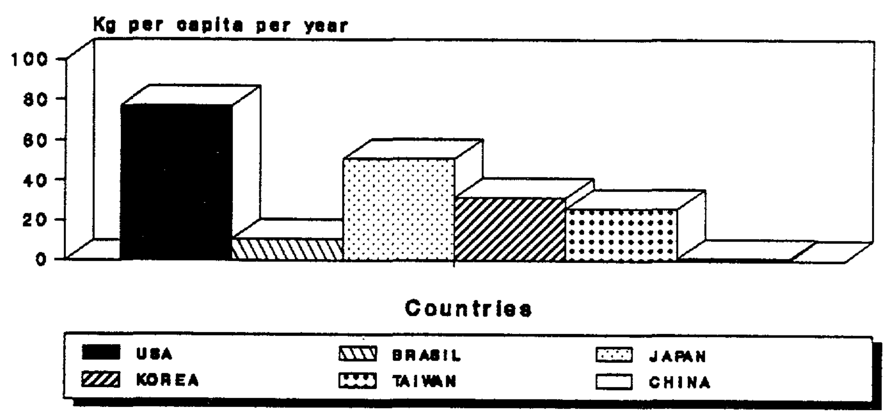
Table 6.15: ASIA--PROJECTED DEMAND FOR PETROCHEMICALS, 1995
(million tpy)

	Developing Asia			
	Six countries	Others /a	Total	Japan
Ethylene	8.2	2.0	10.2	5.1
Propylene	4.7	1.3	6.0	3.8
Benzene	1.8	0.7	2.5	2.7
PE	5.6	1.3	6.9	2.9
PP	2.9	1.1	4.0	2.0
ABS	0.3	0.3	0.6	0.5
SBR	0.8	0.7	1.5	0.5
Polyester fiber	4.8	n.a.	n.a.	n.a.

/a Includes Singapore, Philippines, Hong Kong and Taiwan.

Source: Staff estimates.

Figure 6.1
PERCAPITA CONSUMPTION OF ETHYLENE



Source: Staff estimates

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ANNEX 1

HISTORICAL SERIES OF PETROCHEMICAL PRICES AND MARGINS

Table A1-1: HISTORICAL SERIES OF PETROCHEMICAL PRICES IN THE US
(Constant 1988 US¢/kg)

Year	Index 1988=100	Ethane	Ethylene	Propylene	Butane	Benzene	Methanol	LDPE
1978	59.6	17.6	48.2	36.2	75.8	0.0	24.5	114.6
1979	67.6	17.3	55.5	39.2	79.9	0.0	25.6	119.1
1980	74.1	25.2	71.4	50.6	95.1	0.0	32.3	139.0
1981	74.5	28.1	84.3	57.7	118.4	67.8	35.7	125.8
1982	73.5	21.4	51.0	60.0	108.0	62.6	36.2	89.9
1983	71.6	19.6	61.6	57.0	100.0	61.5	21.5	98.5
1984	70.3	28.3	61.2	62.2	94.0	56.9	16.4	128.6
1985	71.0	23.0	46.5	51.5	91.5	63.7	24.4	96.2
1986	84.0	13.9	38.1	36.8	36.8	28.5	13.5	73.5
1987	92.3	12.0	36.3	33.5	45.4	51.9	10.4	74.0
1988	100.0	11.7	63.9	43.0	39.7	32.3	10.3	88.2

Year	HDPE	PP	PS	PVC	SBR	Propane	Styrene	ABS
1978	108.4	110.9	107.2	99.8	151.7	19.5	66.6	186.2
1979	118.0	114.2	133.7	107.7	149.4	20.7	114.2	218.9
1980	133.3	140.4	136.3	102.7	170.0	28.9	106.2	229.4
1981	125.2	147.7	147.7	88.7	191.9	32.6	111.0	181.2
1982	114.0	120.0	120.0	69.0	159.2	32.1	89.9	224.5
1983	124.7	123.2	110.9	89.2	132.4	35.9	92.3	230.4
1984	109.8	125.5	128.6	109.8	162.2	33.3	103.6	200.6
1985	127.3	102.5	99.3	77.6	133.5	26.5	93.1	201.4
1986	91.9	81.3	88.0	76.1	110.2	13.7	52.5	163.1
1987	76.4	90.8	124.2	81.3	108.7	12.9	114.6	162.4
1988	108.0	108.0	127.9	92.6	116.8	10.1	97.0	165.3

Table A1-2: HISTORICAL SERIES OF PRICE MARGINS IN THE US
(US¢/kg in constant 1988 terms)

Year	Ethylene-Ethane	LDPE-Ethylene	HDPE-Ethylene	PP-Propylene	Propylene-Propane	PS-Styrene	PVC-Ethylene	PVC-Benzene	Ethylene-Naphtha
1978	30.5	66.4	60.2	74.7	16.8	40.6	51.7	99.8	48.2
1979	38.2	63.6	62.6	75.0	18.5	19.5	52.2	107.7	55.5
1980	46.2	67.6	61.9	89.7	21.7	30.1	31.3	102.7	27.3
1981	56.2	41.5	40.9	89.9	25.1	36.6	4.4	20.9	40.1
1982	29.7	38.9	63.0	60.0	27.9	30.1	18.0	6.4	10.6
1983	32.0	36.9	63.1	66.2	21.1	18.6	27.7	27.8	22.9
1984	32.9	67.4	48.6	63.3	28.9	25.0	48.6	52.9	25.7
1985	23.7	49.6	80.7	51.0	25.1	6.2	31.0	13.9	11.8
1986	24.2	35.4	53.8	44.5	23.1	35.5	38.0	47.6	22.7
1987	24.3	37.7	40.0	57.3	20.6	9.5	44.9	29.4	36.3
1988	52.2	35.3	44.1	65.0	32.9	30.9	28.7	60.3	28.7

Source: SRI 1989 Chemical Price Update. Price margin defined as the difference in prices between the products and its major raw materials.

ANNEX 2

HISTORICAL EVOLUTION AND FEEDSTOCK SITUATION IN THE COUNTRIES

A. Republic of Korea

Historical Evolution of the Industry

The Korean Petrochemical Industry was initiated in the early 1970s as part of the Government of Korea's efforts to launch an industrial modernization program and as a result of the enactment of the Petrochemical Development Act (1970). The initial intention was to link existing small plants into complexes that would benefit from economies of scale and shared infrastucture. The Industry was initiated with the set up of the Ulsan Petrochemical complex in 1972 (155,000 tpy of ethylene) which was followed by the Youchun complex in 1979 (355,000 tpy of ethylene). Both units are still the core of the current installed capacity for petrochemicals and both were originally developed through forward integration from oil refineries at the selected sites.

The timing of the development of the industry (early and late 1970s) coincided with great turmoil in the petroleum markets. This had important consequences for the industry because (a) Korea does not possess adequate supplies of the required feedstocks and (b) at that time, the markets were just developing and production scales and domestic demand were small. The decrease in domestic demand caused by the second oil shock and the associated industrial recession, resulted in: (a) a lengthly delay in full utilization of the newly installed capacity at Yeochun, (b) prolonged losses for all domestic producers, and (c) postponment of expansion programs. The local producers survived in part because of tariff protection and price regulation (see Chapter 5).

By the end of 1983, the industry began experiencing a second period of growth and plans were made for expansion of local capacity. These plans resulted in the approval of expansion programs for the two existing complexes. By the third quarter of 1989, a new Naphtha based cracker with a 400,000 tpy capacity is expected to start operation at Ulsan, and a 250,000 tpy new unit is expected to be in operation around the same time at Yeochon. A third naphtha cracker is to be commisioned at Yeochon by 1991 bringing total installed capacity at the site up to 950,000 tpy and total capacity in Korea to 1.5 million tons per year.

Growth accelerated in 1986 with the fall in oil prices (and consequent improvement in the economics of naphtha based crackers) and the increase in producer margins. Also, in 1986 the Petrochemical Industry Development Act was repealed, and therefore investors no longer required approval for new investments and gained full autonomy on their decisions. When the law was revoked, naphtha suppliers attracted by the large margins available to the industry, began making plans to produce downstream petrochemicals, and downstream manufacturers already suffering from a shortage of raw materials, proposed to expand their activities to the synthesis of olefins. The result is an ambitious set of expansion proposals that, if implemented, could again double ethylene capacity by 1995 from the levels of 1991. The program of expansions as proposed by individual investors includes at least six additional petrochemical complexes (Table A2-1), represents a major financial commitment from the private industrial sector in Korea, and if implemented will have major repercussions in the requirements for feedstocks and on the trade patterns for petrochemicals in the region. The total investments required by these proposals is about US$4.5 billion.

Table A2-1: KOREA--PROPOSED NEW PETROCHEMICAL COMPLEXES

Proponent	Olefins capacity			Total investment proposed	Proposed start-up date
	Ethylene	Propylene	Butadiene		
	---------	('000 mt)	----------	(US$ bln eq.)	
Samsung	350	175	45	1.3	1992
Komho Petrochemicals	350	190	56	0.7	1993
Korea Petrochemicals	250	148	98 /a	0.4	1991
Hanyang Petrochemicals	350	150	45	0.5	1992
Hiundai Industries	350	175	51	1.1	1992
Honam Petrochemicals	350	190	n.a.	0.5	1993
Total	2,000			4.5	

n.a.: Not available.

/a C4 fraction.

Source: KPIA, staff estimates.

The Feedstock Situation

5. The country possesses no significant reserves of oil or natural gas. The local production of petroleum derivatives comes from six refineries and is complemented with direct imports. Olefins and aromatics synthesis are based on naphtha cracking with a total estimated requirements for naphtha of 20 million barrels in 1988. The two expansions already in construction will increase total requirements to over 55 million barrels by 1991. The industry faces an increasing dependency on foreign supply of feedstocks for

petrochemicals. The new proposals for petrochemical complexes now being considered would severely stretch the availability of naphtha, with the implied requirements for the proposed 6 naphtha crackers estimated at an additional 40 million barrels. The competition for and availability of naphtha remains one of the major issues facing the industry.

B. India

Historical Evolution of the Industry

The petrochemical industry in India is relatively new. Production of basic petrochemicals began in 1966 with the commissioning of a small 20,000-tpy naphtha-based ethylene cracker, followed in 1968 by a 60,000-tpy naphtha cracker in the Bombay area. Both plants were established by the private sector with foreign equity holding (Union Carbide and National Organic Chemicals). Later, recognizing the role of petrochemicals as a key element in industrial development, the GOI moved toward direct promotion of the sector through the establishment of a public-sector enterprise, the Indian Petrochemical Corporation, and the setting up of integrated production facilities. In the late 1960s, an aromatic plant in Baroda owned and operated by IPCL was commissioned. This was followed by an integrated naphtha-based olefins complex with an ethylene capacity of 130,000 tpy including a number of downstream units. Since its commissioning in 1972, this unit became the focus of petrochemical development in the country.

In 1985, after a clear feedstock picture emerged from the Bombay High gas fields, a 300,000-tpy gas-based cracker was planned at Nagothane and was built with World Bank support. The decision to go ahead with the gas cracker and the start-up of construction took place against the background of a worldwide recession in the sector, although it was a response to the increase in the domestic market needs. The cracker and the associated complex are now nearing completion. The growth of the domestic sector and the currently high prices of petrochemicals in the international market will provide strong incentives for full operation from the start.

India's current production of petrochemicals is primarily based on naphtha in relatively small plants and old units and therefore does not benefit from recent advances in technology, capital costs and energy-saving schemes. Further, given the small scale of existing plants and the high cost structure of the Indian capital goods industry, investment cost per unit of capacity installed is high by international norms. Because of these conditions, India's current production of petrochemicals is characterized by high unit costs. To compensate the high unit costs, the Government imposes tariff and nontariff barriers on imports, as well as restrictions on domestic capacity.

In 1986, a study on the prospects of the industry was completed by the GOI, which generally endorsed shifting priority toward the sector and called for: (a) substantial increase in production capacity, (b) raising the standard for minimum scales of production, (c) reduction of tariff barriers and liberalization of the sector, and (d) increased use of natural gas as a preferred feedstock for the industry. Although the high growth projections used in the report will not materialize, many of the conclusions remain valid and some of its recommendations have been adopted.

The Government of India (GOI) is considering a US$6-8 billion investment program for the petrochemical sector within the next decade. This ambitious program is intended to reduce India's growing dependence on petrochemical imports and to optimize the use of gas and exploit its potential for economic production of key petrochemicals and derivatives. The planned indicative investment program assumes that private investors will expand their role in the sector substantially. When new facilities become fully operational, the level of Indian production of petrochemicals based on world scale and new technology will increase domestic competition substantially, improving overall efficiency and unit cost of production in the sector. The most probable priority ranking and phasing of the proposed projects are as follows:

Olefin Plants. (a) an expansion of the Nagothane cracker from 300,000 tpy to 400,000 tpy and associated downstream investments with completion expected by 1993, (b) a new natural gas liquids (NGL) cracker and associated downstream units to be located at Hazira, state of Gujarat; this project will have capacity to produce about 320,000 tpy of ethylene and about 700,000 tpy of final products, and it is expected to be built in two phases over a period of five years with an estimated completion date in 1995; (c) a new 300,000 tpy naphtha cracker and associated downstream units to be located in Vizag, with a completion date after 1995; and (d) a new 300,000 tpy gas-based ethylene cracker with associated secondary units somewhere along the Hazira-Bijaipur-Jagdishpur (HBJ) pipeline to be completed after 1995.

Aromatic Plants. (a) a 200,000 tpy aromatics unit to be located at Manali, near Madras in Tamil Nadu. The expected completion date is 1993; (b) The second project under consideration is a 250,000 tpy aromatics plant to be set up at Salimpur, U.P., with an expected completion schedule in 1995.

Feedstock Situation. India has had relative success, through its effort in exploration, in improving its reserves of hydrocarbons. Petroleum reserves have steadily increased to the current 6.4 billion barrels, while production reached 0.6 million barrels per day in 1988. But, it is in natural gas where the efforts have resulted in substantial improvements in reserves, and where further improvements are expected. Current gas reserves are sized at 22.9 trillion cubic feet (TCF), but are probably underestimated since gas-rich areas have been traditionally underdeveloped for lack of market. Approximately 80% of these reserves are located off the west coast of India. It is at this site where most of the petrochemical development is taking place. Nevertheless, the recent commissioning of the HBJ pipeline should allow developments inland, if the gas transportation costs do not become prohibitive to the industry. Substantial increases in gas utilization can be expected as a result of the existing plans in the power, fertilizer, household and industrial sectors, with gas production planned to increase from 1.0 billion cubic feet per day (BCFD) in 1987/88, to twice as much by 1995. The installed refineries have an estimated capacity of 50 million tpy and are currently running at capacity. The total naphtha available is in surplus today but is expected gradually to be in deficit, with a shortage estimated at 470,000 tons by 1994.

C. China

Historical Development of the Industry

The Chinese petrochemical industry was started in 1958 with the set up of the Gaoquiao Chemical factory in Shanghai and the subsequent construction of small scale ethylene crackers. With the rapid development of the oil industry during the 1970s, more feedstock was made available to the chemical industry and the first large scale petrochemical complexes were built. Through the period 1970-1978, six petrochemical units with a total combined ethylene capacity of 600,000 tpy were comissioned. Technology was obtained trough suppliers in Japan, Western Europe and the US and the contracts were paid in cash. Location and sizes were selected based on feedstock availability, local market sizes, and the restrictions associated with transportation and logistics.

After 1978 the Chinese government decided to apply minimum scale criteria to future complexes and started a program of expansions and revampings for all small and old units. In 1983, the China Petrochemical Company, Sinopec, was formed with the mandate to manage and coordinate at the national level the development and orderly progress of the petrochemical sector. With Sinopec, the Chinese government planned to end defects in management caused by lack of planning, streamline organization, save in raw materials and promote the production of high value added products. Work on four world size crackers started under the aegis of Sinopec. These units were supposed to be installed by the mid-1980s but several delays, in part caused by financing difficulties, postponed their start up and only three of the four had been commisioned by 1989. Today Sinopec directly controls 13 petrochemical plants, 17 refineries and 4 synthetic fiber units. The GOC and Sinopec are now envisaging an additional increase in capacity combined with further revamping of existing units. Four additional petrochemical complexes are expected to be built at Guangzhou, Tianjin, Du Shanzi and Beijing with contract awards expected during the period 1989-91.

The industry still faces severe shortages of many key intermediates and products, serious financial limitations that restrict the ability to expand capacities and secure raw materials and, outside of Sinopec, the effects of a small-scale chemical production system based mostly on outdated technology. All these factors contribute to increase production costs.

Feedstock Situation

China's oil reserves are the largest in the Asia region, totalling about 23.5 billion barrels. The country is also endowed with substantial gas reserves, sized at 32 trillion cubic feet. The Chinese production of crude is about 2.7 million barrels per day, (135,000 tons in 1988) for equivalent reserves of 23 years. However, under the current trends, oil demand is expected to increase at a faster rate than production. If the trend holds, China will eventually have to curtail the level of exports. In 1987 China exported about 0.54 million barrels per day, which represented 20% of total crude production. If oil continues to be diverted to exports without significant production increases, manufacturing industries, including those in the petrochemical sector may experience shortages of raw materials and be forced to operate below capacity.

Table A2-2: CHINA--PATTERN OF CURRENT FEEDSTOCK USE BY THE PETROCHEMICAL INDUSTRY

Complex	Source	Feedstock type	Ethylene capacity ('000 tpy)	Other olefins produced
Beijing Yanshan	Dongfanghong Refinery	Gas oil	300	Propylene (130), butadiene (215)
Lanzhou		Heavy crude oil and gas oil	72	Propylene (20), butadiene
Nanjing	Nanjing Oil Refinery	Naphtha	60	Propylene
Yangzi	Refinery	Naphtha	300	Propylene (140), butadiene
Shanghai Gaogiao	Refinery	LPG, gas oil	30	Propylene, butadiene
Liaoyang Fiber		Naphtha	73	Propylene (35)
Shanghai (Jinshan)		Kerosene, gas oil	120	Propylene (50)
Pilu		Residual oil	300	Propylene (60), butadiene (70)
Daqing	Refinery	Refinery gases	300	Propylene (80)
Jilin	Refinery	Refinery fractions	115	Propylene (50), butadiene (40)
Total			1,670	

Source: CFECT, 1989, and staff estimates.

The management of the refinery sector at the state level is now conducted by Sinopec. The refining infrastructure consists of about 40 refineries, with a distillation capacity of 2.1 million barrels per day; under current expansion plans refining capacity should increase to 2.5 million barrels per day by 1990. If demand grows at 4% per year, even the current expansion program will prove insufficient to meet consumption.

Table A2-3: CHINA--ETHYLENE PLANTS UNDER CONSTRUCTION

Plant	(Location)	Ethylene capacity ('000 MT)	Expected start-up date
Shanghai	(Jianshan	300	1991
Fushun	(Liaoning province)	120	1991
Panjin	(Liaoning province)	130	1990
Punajg	(Henan province)	140	1992

D. Thailand

Historical Evolution of the Industry

The petrochemical sector is a newcomer in Thailand. Petroleum and gas resources were first identified in 1970, and only in 1981 the first pipeline was completed to connect the offshore gas fields with power plants outside of Bangkok. As a result of these developments and with the goal of maximizing the value added of gas fractions, the Government of Thailand (GOT) formed in mid-1981 a committee on the petrochemical industry with the mandate to come up with recommendations for its future development in the country. The Petroleum Authority of Thailand (PTT) which provides the secretariat to the committee, asked the IFC to review the various reports and studies prepared on the subject and develop recommendations. In 1984, PTT resolved to set up a petrochemical complex sized to meet the domestic demand for commodity polymers using natural gas fractions as feedstock. The National Petrochemical Company (NPC) was formed in 1984 and construction of a complex was started in 1986 with IFC participation. Start-up is expected by the end of 1989.

With the operation of the first petrochemical complex (known as NPC-1), Thailand will become an important producer of commodity polymers in the region with important repercussions for local processors and manufacturers; still, the country will remain a net importer of styrenics and aromatic derived products. To satisfy these market requirements, and also with the intention to tap into perceived export opportunities, the GOT is in the process of examining, with IFC assistance, the viability of an aromatics and an olefins complex to be located next to a refinery and in the area of Ma tha Put, on the eastern seashore, respectively. The GOT is also considering the establishment of a reformer to feed the aromatics component of the complex. A report has been prepared on the subject and a decision is expected some time in 1989.

Feedstock Situation

The development of Thailand's indigenous hydrocarbon resources has progressed vigorously during the last decade. In 1979, Thailand had to import 90% of its oil, mostly from the Middle East. Since then, self-reliance has increased to about 55% of total requirements. Oil production in 1987 equaled 32,000 barrels per day. Total crude reserves are now estimated at 85.2 million barrels. Natural gas development has proceeded at an even faster pace. Total gas reserves are now estimated at 3,720 bcf and production reached 172 bcf in 1988. GOT plans call for gas production to reach 700 mcf per day by 1991. With the development of the gas fields and associated processing infrastructure, (including the PTT gas separation plants), Thailand is now able to use gas and gas fractions as fuels and raw materials for the power, household and industrial sectors. A second gas PTT gas separation plant is expected to come on stream in 1989 and will double the capacity of separation of gas fractions.

There are three commercial refineries in Thailand with a total capacity equivalent to 194,000 bpd. Refining is done by Thai Oil, Bangchak and Esso, but the capacity installed is not sufficient to meet the local demand of derivatives, in particular for light distillates and LPG. The country is also in the process of implementing an expansion program for the refinery sector. Total capacity is expected to reach 292,000 bpd in 1990 after expansions at Thai Oil and Esso come on-stream. Additionally, four new refineries have been proposed by foreign investors that could eventually again double the refinery capacity by 1992/93.

Ethane and propane will be available from the gas separation plants. The tonnage available from both units is summarized in Table A2-4. This is enough to feed NPC-1, but other sources of ethane are required for the new complex under consideration. The alternatives under consideration include the use of light naphtha, the increase in ethane separation capacity and the use of condensates. Still, the fact remains that unless immediate additional investments in refinery or gas separation facilities are implemented, the feedstock issue will constrain the future shape and size of the petrochemical sector.

E. Malaysia

Historical Development of the Industry

Proposals for the establishment of a basic petrochemical complex in Malaysia can be traced back to the early 1980s. But the uncertainties in the market and the ensuing economic recession dissuaded the Government of Malaysia

Table A2-4: THAILAND--ETHANE SUPPLY/DEMAND BALANCE
('000 tpy unless otherwise indicated)

	GSP 1	GSP 2
Gas throughput		
(MMSCFD)	350	250
Products		
Ethane	310	70
LPG	430	293
Natural gasoline	82	82
Start-up year	1984	1990
Cracker requirements		
NPC-1	354	
Second olefins complex /a	370	

/a In ethane equivalent, based on an ethylene capacity of 350,000 tpy.

(GOM) from endorsing the proposals. Nevertheless, plans went ahead by the private sector and Petronas itself to build and operate a number of downstream plants for the manufacture of resins and elastomers for the domestic market and for the construction of a methanol plant at Laboan, dedicated to exports.

A new master plan for the petrochemical industry was prepared by Petronas in 1985 and later adjusted to reflect the stage of progress in the availability and supply of natural gas and natural gas liquids. In the plan, an olefins complex as well as some specialties and derivatives (MtBE and Polypropylene) have been targeted for development. Petronas is in the process of implementing a 300,000 tpy MtBE plant and a 80,000 tpy polypropylene unit, based on dehydrogenation of butane/propane obtained from natural gas processing on the East Coast of the Malaysia Peninsula. Both units are expected to start operation in 1992, are being developed with foreign partners, and are primarily dedicated to exports, with the PP plant also meeting the local requirements. Parallel to these developments, the plastics industry has slowly increased its production capacity, effectively promoting the growth of the plastics in Malaysia and contributing to the exports of manufactured goods.

Feedstock Situation. Malaysia is a large producer of Oil, fifth after China, Indonesia, India and Australia in the Asia-Pacific region. The current reserves are sized at 2.9 billion barrels with a production rate of 2.3 million barrels per day. Gas reserves are conservatively estimated at 52,000 billion cubic feet and are sufficient to last over 100 years at the current production rate. Malaysia is also an LNG exporter (to Japan) with annual volumes estimated at 6 million tons per year. The infrastructure for gas distribution and processing has been steadily increased during the last years, and is expected to continue improving to include main gas lines between the east and west coasts of the peninsula and from the east coast to Singapore.

F. Indonesia

Historical Development of the Industry

Despite the several attempts in the last 15 years, the abundant volume of gas and oil resources, the installed refining infrastucture and the strategic geographical location, the petrochemical industry has yet to establish its first olefins complex in Indonesia and has only very recently cristallized plans for the construction of an aromatics plant. At least three times in the past, an olefins complex has been proposed and cancelled.

Table A2-5: INDONESIA--STATUS OF PROPOSED AROMATICS AND OLEFINS COMPLEXES, MID-1989

	Capacities		Proponents	Issues pending	Proposed start-up
Aromatics	405,000	benzene	Thyssen	Feedstock supply	1992
(at Aceh,	50,000	toluene	Rheinstall (W. Germany)		
Sumatra)	217,000	p-xylene	and Humposs (Indon.)		
Olefins	375,000	ethylene	Shell Mitsubishi	Financing guarantees	1993

The reasons for the continuous delays in the implementation of the industry are many: some of the failures can be attributed to the variations in the oil markets and its linkage with the financial health of Pertamina, part to the difficult balance of payments situation experienced during the 1980's and part to a lack of clear long range development program for the industry. Also, there has been some confusion about the actual availability of feedstock resources for the industry. This is in particular ironic, given the current status of the country as a large oil, LNG and LPG exporter and has to do with the nature of the long term export contracts of these fuels which imply use of NGLs to achieve minimum caloric content of the exported gas.

The growth in domestic markets has already created a large enough base to justify world size plants to be located in the country. Therefore, a number of new and old proposals are again being reviewed and some have gone beyond the planning stage. These include ambitious projects for the production of olefins, aromatics, synthetic resins and rubbers and specialty chemicals. For example, in 1988, construction began on an aromatics unit in CILACAP under the sponsorship of Pertamina. This unit is expected to feed from the CILACAP refinery and will produce 120,000 tons of benzene and 270,000 of paraxylene. Plans for a large aromatics plant at Aceh (Sumatra) and an ethylene cracker possibly located at CILACAP are still under discussion, with feedstock arrangements and financing among the pending issues. The planned aromatics plant output is earmarked for exports (405,000 of benzene, 217 tons of paraxylene) while the olefins unit would meet the domestic market requirements for ethylene and propylene derivatives (Table A2-5)

Feedstock Situation

Indonesia has abundant oil and gas resources. Estimates of the reserves are placed at somewhere between 8-10 billion barrels of oil and about 83 trillion cubic feet. Also, natural gas is becoming an increasingly important energy and feedstock material in the country. Natural gas production in 1987 reached 1.7 trillion cubic feet, with most of it being used domestically for industrial purposes, including its use as feedstock in fertilizer production and as feedstock and fuel in refineries and LNG/LPG plants.

Table A2-6: INDONESIA--GAS UTILIZATION, 1987

	Billion cubic feet
Production	1,737
Own use	396
Net production	1,423
Sales	1,188
Electricity	5
City gas	1
Industrial users	
Fertilizers	140
Cement	3
Cilamaya	78
Refineries	21
LPG plants	24
LNG plants	917
Other	1
Flared	147

Source: The Petroleum Report. Indonesia US Embassy, Jakarta.

Indonesia is the world's largest exporter of LNG, supplying about 40% of the total merchant market, an amount equivalent to 0.85 trillion cubic feet in 1988. The proximity to Japan and the large gas reserves have allowed the country to develop the most sophisticated LNG export operation in the world. At present, there are ten LNG production facilities with an installed capacity of around 900 million cubic feet per day of product. Close to 80% of the LNG exports go to Japan. Other LNG customers include South Korea and Taiwan. In 1988, the LPG fractionation plants at Arun and Bontang were commissioned with a combined capacity of 2.2 million tons and exports were initiated with the first shipments to Japan. The new fractionation capacity and the proximity to large net importing markets of LPG, provide an opportunity for Indonesia to also become one of the largest world producers and exporters of LPG. Additional LPG capacity is now under construction and more is being considered.

There are six refineries with a total throughput capacity of 900,000 barrels per day. At present, Indonesia is self sufficient in fuel and derivatives products and still allows for surplus refining capacity. The total current naphtha production is estimated at 19 million barrels. In addition, a new refinery is being built in West Java by Pertamina that will increase the total refinery capacity by 125,000 barrels per day. Despite the abundant resources and privileged position in petrochemical raw materials (naphtha, LPG, NGL), the supply of feedstock has surfaced as an issue in both the aromatics and olefins projects under consideration, with Pertamina not guaranteeing the supply of domestic naphtha to the proposed aromatics plant at Aceh and questions being raised about the availability of NGL to the olefins unit.

ANNEX 3

FEEDSTOCK VALUATION AND PRICES

A. General Principles of Ethane Valuation

Ethane is a component of natural gas. The percentage of ethane in natural gas varies significantly. While associated gas is generally ethane-rich (15-20% by volume, 20-25% by weight), nonassociated gas is not (2-3% by volume, 2-5% by weight). If ethane is not extracted from the gas stream, its cost and value on a thermal basis 1/ then extraction costs should be added to the price of ethane and its value should exceed the value of gas.

2. Thus, the cost of ethane depends on the opportunity cost of gas in a particular country or area. There are two approaches to the determination of the economic value of natural gas, which in turn, depend on its availability relative to present and future use, the cost-based approach, and the value-based approach:

(a) If reserves are so large that a new ethane-based olefin plant will not divert gas from other current or foreseeable use during the operating life of the plant, but will simply require the production of the necessary additional quantities of gas, the opportunity cost of natural gas from which ethane is extracted is simply the cost of producing and transporting gas to the plant. A depletion allowance is added, which reflects the discounted present value of the replacement fuel, which in turn varies with the expected timing of full commitment of the reserves and the value of the replacement fuel at that point to meet subsequent incremental needs.

(b) If reserves are such that use as feedstock in an olefin plant would divert the gas from other current or planned uses (e.g., power generation, industrial or residential fuel use, other feedstock use), the opportunity value of the natural gas will be the value of the replacement fuel in these other uses (adjusted for transport to the different locations) or, for feedstock, the net-back value of the gas in these other uses.

To the opportunity cost (or value) of natural gas, the cost of separating the ethane from natural gas must be added. This cost is estimated at about US$1 per million BTU of gas throughput on average, nut varies depending on the percentage of ethane one wants to recover from the gas (the higher this percentage, the more expensive the extraction). Also, ethane separation is normally carried out at plants which also carry out separation of LPG. Therefore, separation is cheaper where carried out in an existing, large LPG plant, with an existing market for methane (C1 fractions, which make the bulk of natural gas). Because ethane represents only a fraction of natural gas feedstock (typically ranging from 2-5% for nonassociated gas and

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1/ 0.565 cubic feet of ethane has the same caloric content as 1.000 cubic feet of pipeline quality gas.

15-20% for associated gas but with possible significant deviations from these averages) ethane separation is normally economically justified only under a set of circumstances described below:

- Gas used is associated gas currently flared. The cost of gas production is zero since it comes as a by-product of oil production. Even if there is no market for the methane fraction (which would on average account for 50% to 60% of the gas), ethane separation for ethylene production is justified since feedgas comes to the separation plant free of charge.

- Gas is nonassociated and there is no market for methane (as fuel substitution or feedstock). Unless incremental costs of gas extraction are very low and the gas is rich in ethane, it is usually no economical, for ethylene production, to separate ethane and other NGL fractions from methane: with 90% by weight of gas being methane, processing of 10 times the usable portions would be required. If gas productions costs are, say $0.6 per MMBtu, the total cost of gas feed alone to the separation plant would amount to $6 per million BTU, or $7 per MMBtu of NGLs when adding the separation charge. At this cost, ethane is no longer competitive with naphtha; there may be however, cases where the required quantities of nonassociated gas are produced from ethane-rich fields at a lower cost (as low as US$0.20/MBtu). In this case, the extraction of ethane and other heavier gas fractions may be economical even if methane has to be flared.

- Gas is nonassociated but there is a market for ethane as fuel substitution or feedstock to other industries (ammonia, methanol, LNG, steel). NGL separation for ethylene production then becomes economic again as the methane fraction can be sold at the production cost of gas feed or higher.

The combination of the opportunity cost (or value) of natural gas and the economics of separation plants gives a range of economic value of ethane which are illustrated on the next page. Surplus associated gas provides the best competitive advantage, followed by surplus nonassociated gas and, last, gas (associated or nonassociated) with an alternative use as fuel replacement. In the case of surplus nonassociated gas with a low NGL content, however, one has to reiterate the critical importance of securing markets for volumes of methane which may be very large: a 450,000 tpy ethylene plant requires 560,000 tons of ethane, or 15.5 billion SCF per year. With the NGL content of nonassociated gas typically ranging from 4% to 8% and assuming that all NGL portions can be economically recovered, this means that a market for 190-390 billion SCF per year of methane has to be found. The orders of magnitude presented here are only illustrative of typical cases. Significant differences from these typical cases can occur depending on the composition of the gas, and the location of the plant, and of other energy or feedstock users relative to the gas source. For instance, if the olefin plant is located a long distance away from the gas source, the cost of gas supply may increase significantly.

The above principle refers to the economic valuation of ethane. The financial price actually charged may differ, reflecting the outcome of negotiations with users and cross-subsidies between the different gas fractions. For instance, in Saudi Arabia, the cost of gas separation was allocated equally between methane and other fractions. Although there is no economic justification for this (all gas fractions can be used as energy source), the price of methane still remains much below all other possible energy sources and permitted the low ethane price charged to the petrochemical industry ($0.5/MMBtu). When the price of natural gas is high (i.e., equals the price of alternative energy sources) charging part of the ethane separation costs is not feasible since it would lead users to switch to these other sources.

Table A3-1: ECONOMIC VALUATION OF ETHANE FEEDSTOCKS, 1988

Item	Associated gas	Nonassociated gas		Associated or nonassociated gas
Gas supply in relation to demand	surplus	surplus		deficit
Market for methane	irrelevant	yes	no	yes (all fractions)
Value of ethane (US$/MMBtu)				
Opportunity value of natural gas				
Incremental cost of production (per ton of ethane)	0	0.5-1.0	6.0-10.0	
Depletion allowance	0	0.3-0.6	0.3-0.6	
Value in alternative uses: example				
Fuel oil				2.3
Coal /a				2.0-2.4
Separation cost	1.0	1.0	1.0	1.0
Total opportunity cost/value of ethane	1.0	1.8-2.6	7.3-11.6	3.0-3.4/b

/a In new, purpose-built coal-based plants (this figure takes into account the higher investment costs in coal-based plants compared to fuel oil or gas-based plants).

/b Separation costs in Thailand are $1.6 per MMBtu, thus the value of ethane is close to $4.0.

Notes: This presentation includes estimated depletion allowances to arrive at the opportunity cost of gas. As full commitment of gas reserves is approaching, inclusion of the depletion allowance will raise this value closer and closer to the value of the replacement fuel. Use for methane is assumed to be nearby the gas source and the location of the olefin plant. If this is not the case, proper adjustments have to be made for gas transport costs.

Principles of Ethane Valuation in Indonesia

General. Indonesia is very rich in energy resources, oil, gas and coal. With LNG exports now reaching 0.9-1.0 TCF per year, gas reserves in excess of current and prospective LNG requirements can be considered as nontradeable. Natural gas reserves are also well in excess of present and forecasted domestic requirements until the end of the century. Natural gas reserves are essentially on nonassociated gas (92%). About 8% of the gas produced is still flared, but, due to dispersion and distance to possible users, recovery is not considered economical.

The opportunity value of gas varies with regions. Gas reserves are far larger in North Sumatra and East Kalimantan than in South Sumatra in Java. In North Sumatra and East Kalimantan, where a major LNG industry has been established, availability of gas is far larger than any present or planned use, and will remain so even if the Kalimantan gas fields are eventually linked to Java, the major energy consuming area of the country. The situation also varies within Java: in East Java, recent discoveries show that the production potential far exceeds the current level of consumption and these reserves are not expected to be fully committed until the end of the century. Subsequently, if additional reserves are not found near or in Java, provision of gas from Kalimantan will continue to ensure gas availability to match incremental requirements. In West Java, gas supply from nearby fields is constrained today, but, with proper development of gas distribution networks, these fields should be able to supply requirements for the coming years. Subsequently, if economical, gas might be provided via a link with East Java and Kalimantan. The opportunity cost of gas in Indonesia is therefore essentially linked to the production and distribution cost of gas since gas supply is not a constraint for a long time to come. The table on the next page provides a range of values showing the estimated opportunity cost in each region and the expected price range.

Principles of Ethane Valuation in Malaysia

As in Indonesia, Malaysia has vast gas resources, the utilization of which is limited by the low build-up of the domestic demand. These major resources are located off the east coast of peninsular Malaysia and in Sarawak (and Saban to a lesser extent). In both regions, gas will remain in surplus of foreseeable use for a long time.

Gas resources near the peninsula are of both associated and nonassociated gas. The ethane content of gas is high, 8% on average (5% propane, 15-16% of C2/C3/C4 fractions), which is favorable to petrochemical development (less gas needs to be processed, thus a lesser market needs to be secured for methane). In Sarawak, gas is 90% nonassociated lean gas. In Sabah, gas is both associated and nonassociated.

In peninsular Malaysia the existing market for methane is presently insufficient to support ethane separation for a world-scale ethylene plant, but is expected to become sufficient in 1992/93 when the pipeline to connect west coast power plants and Singapore, and the second separation plant are completed. Gas throughput will then reach about 180 billion SCF per year, of

Table A3-2: INDONESIA--ESTIMATED ECONOMIC VALUE OF ETHANE
(In constant 1988 terms US$/MMBTU ethane)

Item	Year	North Sumatra	E. Kali-mantan	East Java	West Java	South Sumatra
Supply in relation to demand	1988	surplus	surplus	surplus	deficit	surplus
	1995	surplus	surplus	surplus	balance/a	n.a.
	2000	surplus	surplus	surplus	surplus/b	n.a.
Type of gas		nonassoc.	nonassoc.	nonassoc.	assoc.& nonassoc.	nonassoc.
Market for methane (bln SCF/yr)		sufficient LNG, fertilizer	sufficient LNG, fertilizer methanol	insufficient/c	insufficient/c	insufficient
	1988	(over 400 for LNG alone)	(over 500 for LNG alone)	-- 80-100 --		(50-100)
	1995			--- 200 ---		
	2000			--- 330 ---		
1. Average incremental cost of gas production		0.6	0.6	0.7	1.0	0.5
2. Transport to user		0.1	0.1	0.3 0.8/d	0.2 1.4/d	0.1
3. Depletion allowance (@ 5% DF)	1988	0.4	0.4	0.3	0.3	0.4
	1995	0.5	0.5	0.5	0.5	0.6
	2000	0.7	0.7	0.7	0.7	0.8
Opportunity cost of gas	1988	1.1	1.1	1.3	1.5	1.0
	1995	1.3	1.3	1.9	2.6	1.2
	2000	1.5	1.5	2.1	2.9	1.4
Value in other uses: LNG net-back /e	1988	0.8	0.8			
	1995	2.0	2.0			
Coal substitute (power plants)	1988			2.0	2.0	
	2000			2.0	2.0	
Fuel oil (power plants)	1988			2.3	2.3	
	2000			3.2/e	3.2/e	
Opportunity cost (or value) of gas in area	1988	1.1	1.1	1.3	2.3	1.0
	1995	1.3	1.3	1.9	2.0	1.2
	2000	1.5	1.5	2.0	2.0	1.4

Table A3-2 (continued)

Item	Year	North Sumatra	E. Kalimantan	East Java	West Java	South Sumatra
Cost of ethane separation		1.0	1.0	1.0	1.0	--
Economic value of ethane	1988	2.1	2.1	2.3	3.3	2.0
	1995	2.3	2.3	2.9	3.0	2.2
	2000	2.5	2.5	3.0	3.0	2.4

/a Assuming new reserves are found to supply requirements of area.
/b With connection to East Kalimantan via East Java.
/c Unless a significant portion of this gas is associated.
/d Gas from East Kalimantan.
/e Assuming LNG CIF Japan = $3 per MMBtu at the end of 1988 (increasing in line with Bank projections of crude oil price (para. 4.5) less transport to Japan at $0.6 per MMBtu) and with cost of liquefaction ($1.6/MMBtu).

which it should be possible to extract about 14 billion SCF of C2/C3 to feed a 400,000 tpy cracker, with possibilities for further expansion to up to 550,000 tpy by year 2000 if demand for methane develops as projected.

In Sarawak, the market for methane outside LNG production is and will remain limited (only about 22 billion SCF per year in 1987), while at the same time, the content of ethane and heavier fractions is low. LNG production provides a large outlet for methane, since gas throughput for LNG is about 455 billion SCF per year, but gas is lean, with an ethane content of only about 1% by volume (about 2% by weight). Even if LNG contracts could be renegotiated enough ethane would not be available to feed even a 300,000 tpy plant. Later on, if LNG sales are increased to the capacity of the gas pipeline to the LNG plants, there might be sufficient NGLs for a 300,000 to 400,000 tons plant. However, given the uncertain prospects of new LNG investments today resulting from competition of cheap fuel oil and coal priority should be given to petrochemical development on the East Coast of the Peninsula in view of its more favorable resource base to support a larger plant. In Sabah, both reserves, and present and future markets for methane are far too limited to support world-scale petrochemical development.

In Peninsular Malaysia and Sarawak, the opportunity value of gas is determined by its long-range marginal cost, plus a depletion premium. The estimated economic value of gas and ethane in the two regions is summarized on the next page.

Table A3-3: MALAYSIA--ESTIMATED ECONOMIC VALUE OF ETHANE
(US$/MMBTU ethane)

Item	Year	East Peninsula	Sarawak
Supply in relation to demand	1988	surplus	surplus
	1995	surplus	surplus
	2000	surplus	surplus
Type of gas		nonassoc. and assoc.	nonassoc.
Market for methane		sufficient after 92/93	sufficient /c
(Billion SCF/year)	1988	90 bi SCF/y	455 bi. SCF/y
	1995	180 bi.SCF/y	(LNG)
	2000	300 bi.SCF/y	up to 650 bi SCF
1. Average incremental cost of gas production		1.1 /a	0.2
2. Depletion allowance /b	1988	0.6	0.6
	1995	0.8	0.8
	2000	1.1	1.1
3. Transport to user		--	--
Total (1+2+3)	1988	0.8	0.8
	1995	2.0	2.0
	2000	2.2	1.3
Value in Other Uses			
LNG net back /d	1988	0.8	0.8
	2000	2.0	2.0
Coal substitute (power plants)	1988	2.4	2.4
	2000	2.6 /e	2.6 /e

Table A3-3 (continued)

Item	Year	East Peninsula	Sarawak
Value in Other Uses (cont.)			
Fuel oil (power plants)	1988	2.3 /g	2.3 /g
	2000	3.2 /f	3.2 /f
Opportunity cost of gas in area	1988	1.7	0.8
	1995	1.9	1.0
	2000	2.2	1.3
Cost of ethane separation		1.0	1.0
Economic value of ethane	1988	2.7	1.8
	1995	2.9	2.0
	2000	3.2	2.3

/a Cost of production and distribution to mainland terminal.
/b Based on marginal replacement for gas
/c Provided LNG content can be negotiated.
/e Assuming: LNG CIF Japan = $3.0 per MMBTU at the end of 1988, increasing in line with Bank projections of crude oil price; less transport to Japan ($0.6) and cost of liquefaction ($1.6).
/f Increasing in line with Bank projections of coal prices
/g Fuel oil equivalent, increasing as Bank crude oil price projections.

China

Gas reserves in China are mostly of nonassociated gas, and are mostly located in the Sichuan province (which represents 80% of natural gas used in China), the balance being in the North East, near the Daquing and Dagang oil fields, and near Hainan island. Although proved reserves are sufficient to last 60-70 years at the 1987 production level, gas use today is much below its potential use as coal replacement in cities. Production in 1987 for China as a whole of coal gas, LPG and natural gas was only the equivalent of 114 billion SCF of natural gas, of which natural gas represented only 53 billion SCF. Gas situation is tight in all major cities. The demand for gas in any form, present and potential, is much greater than the present and potential supply. The opportunity value of natural gas is not available at this stage, but is likely to be relatively high, if natural gas is assumed to substitute for coal gasification in cities. In the absence of better information, one has assumed that the opportunity value of gas in China was at least the fuel oil equivalent. In any case, prospects for petrochemical development from natural gas appear seriously constrained for the coming decade due to the lack of associated gas reserves, the small present use of methane from nonassociated gas, and the foreseeable competition from other uses. For that reason, existing major complexes are based on cracking of heavy feedstock (crude oil, gas oil, naphtha and refinery gases), and China is, at this time, contemplating petrochemical production only from naphtha.

Principles of Ethane Valuation in Thailand

Thailand is a net energy importing country, with production of domestic natural gas and petroleum meeting about 30% of hydrocarbon demand. Any additional oil and gas produced will have a ready access to the domestic market, in particular for power generation where the use of oil during the 90's will still be substantial. The opportunity value of natural gas is thus linked to the fuel oil parity.

Total gas production (mostly offshore in the Gulf of Thailand) in 1987 amounted to 190 billion SCF, out of which 128 billion was processed through a gas separation plant. The cost of producing and delivering gas is rather high, US$2.1/MMBTU on average in 1988. The offshore gas is rich in NGL, with an average ethane content of 8.3% by volume and propane content of 5.1%. Thus the separation plant will be able to produce sufficient C2/C3 (350,000 tons of ethane and 86,800 tons of propane to feed the NPCL olefin plant to come on stream in 1989 (256,000-315,000 tons/yr of ethylene). Production of sufficient quantities however, requires recovery of a high percentage of the ethane (85%), which probably explains the high cost of separation in the gas plant ($1.6 per million BTU of ethane).

A second gas separation plant is due to come on stream by 1990 (with a total troughput capacity of 73 billion SCF. Incremental ethane produced, however (about 50,000 tons) will be far short of requirements of a second gas-based cracker, but could complement the ethane feedstock of the first cracker. Later on, by 1995, new gas supplies will come from the Texas Pacific fields and will provide an additional 90 billion SCF per year. Based on recovery efficiencies similar to the first plant, a third separation plant at that point could provide about 230,000 tons of ethane per year (to produce 185,000 tons of ethylene), which could either justify an expansion of the first cracker, or possibly the construction of a new cracker designed to use a variety of feedstocks, including a large proportion of ethane. Studies are under way to assess the feasibility of a second complex essentially based on natural gasoline, condensates and domestic and imported naphtha, but the use of additional quantities of ethane to become available by the early and mid-90s has not been established.

As stated earlier, the opportunity cost of gas is estimated at the imported fuel oil equivalent ($2.3/MMBtu), plus separation costs ($1.6 per million Btu). Thus, the opportunity cost of ethane in 1988 may be estimated at about US$3.9 per million Btu, subsequently increasing according to international fuel oil prices.

Principles of Ethane Valuation in India

Natural gas in the western and northern regions of India is supplied through the HBJ pipeline, by the gas fields offshore of Bombay. Total potential supply is estimated at between 1,765 and 3,180 million SCF per day

Table A3-4: OPPORTUNITY VALUE OF ETHANE
(US$/MMBtu)

	1988	1990	1995	2000
Imported fuel oil equivalent	2.3	2.5	2.9	3.7
Separation cost	1.6	1.6	1.6	1.6
Total	3.9	4.1	4.5	5.3

by the end of next decade. Consumption of natural gas by the higher net-back uses such as petrochemicals, fertilizer, LPG and peaking turbines for power generation are unlikely to consume all available supplies at any time over the next 10-20 years. On the other hand, potential gas requirements for base-load (combined cycle) power generation are so large that it could absorb any amount of gas supplied in the western region. The net-back value of gas in this case is based on the value of alternative energy sources, coal or fuel oil. While a good part of India's domestic coal provides the cheapest base-loan power, the distance of domestic coal mines to the western region results in close competition of fuel oil, which has been assumed to be the cheapest alternative fuel in that region. The opportunity cost of natural gas can therefore be estimated at the fuel oil, which has been assumed to be the cheapest base-load power, the distance of domestic coal mines to the western region results in close competition of fuel oil, which has been assumed to be the cheapest alternative fuel in that region. The opportunity cost of natural gas can therefore be estimated at the fuel oil equivalent.

The gas separation plant in Uran already has the required capacity to supply the ethane needed for the gas-based ethylene cracker in Maharashtra, including for its planned expansion from the current 300,000 tpy to 400,000 tpy. Future availability of C2/C3 (about 70/30), however, will depend on the speed at which markets for the methane fractions will materialize for gas marketed at the Hazira landfall point, in particular on actual construction schedules for six fertilizer and 3 power plants presently under implementation or planning, and on Government decision to modify existing power plants for gas use. When all markets for planned gas production have been developed, there will probably be room for at least one more gas-based cracker (total gas output at Hazira is expected to reach 20 million cubic meters per day, or 268 billion cubic feet per year; assuming an average 5% C2/C3 content, 13.4 billion SCF of C2/C3 could be extracted, enough to feed a 400,000 tpy cracker). The timing for all these investments and for a second gas separation plant in Hazira, is very uncertain at present.

Based on the opportunity value of natural gas discussed above and ethane separation costs estimated at about US$1.0 per million BTU of natural gas, the opportunity value of ethane in India can therefore be estimated as follows:

Table A3-5: OPPORTUNITY VALUE OF ETHANE IN INDIA
(US$/million Btu)

	1988	1990	1995	2000
Natural gas	2.3	2.5	2.9	3.7
Separation cost	1.0	1.0	1.0	1.0
Total	3.3	3.5	3.9	4.7

B. Naphtha Valuation and Prices

Table A3-6: PROJECTED ECONOMIC (WHOLE-RANGE) NAPHTHA PRICES
(Constant 1988 US$/MT)

	1988	1990	1995	2000
India (Net importer)				
CIF Bombay				
FOB Singapore	140	155	168	202
Freight	12	12	12	12
Total	152	167	180	214
South Korea (Net importer)				
CIF Korea				
FOB Singapore	140	155	168	202
Freight	10	10	10	10
Total	150	165	178	212
Malaysia (Net importer)				
FOB Malaysia				
FOB Singapore	140	155	168	202
Thailand (Net importer)				
CIV Thailand				
FOB Singapore	140	155	168	202
Freight	8	8	8	8
Total	148	163	176	210
Indonesia (Net exporter)				
FOB Indonesia				
FOB Singapore	140	155	168	202
China (Net importer)				
CIF China				
FOB Singapore	140	155	168	202
Freight	10	10	10	10
Total	155	165	178	212

Table A3-7: NAPHTHA COST DIFFERENTIAL BETWEEN ASIAN PRODUCERS AND PRODUCERS IN OTHER REGIONS, 1985-88
(US$/MT in current terms)

	US	Western Europe	Middle East
Malaysia and Indonesia (net naphtha importers)	-26	-5	+13
China, India, Thailand and Korea (net naphtha exporters)	-16	+5	+23

Source: Staff estimates.

Table A3-8: INTERNATIONAL PRICES OF NAPHTHA
(US$/MT, FOB)

	Rotter-dam	Mediter-ranean	Middle East	Singa-pore	Carib-bean	US Gulf Coast
1978	145.2	139.5	129.8	127.7		128.6
1979	309.7	296.6	211.8	197.2		263.2
1980	324.8	313.7	315.0	302.5	318.3	285.7
1981	336.6	317.0	315.7	331.0	332.9	336.8
1982	295.8	284.9	304.3	310.6	323.1	314.4
1983	274.8	267.4	263.4	263.4	290.7	288.9
1984	248.3	238.7		243.6	261.3	268.0
1985	244.5	234.3		241.8	259.9	266.4
1986	126.7	118.0	116.9	126.3	135.5	148.2
1987	160.0	150.3	145.0	158.5	170.8	180.4
1988	143.6	130.5	125.3	139.6	157.3	176.1
1989 (Jan-May)	170.3		150.5	153.5	173.0	198.5

Sources: FOB Rotterdam and Mediterranean, 1978-88, "International Crude Oil and Produce Prices," January 1989 (Energy Economics Research Ltd.); 1989, Petroleum Market Intelligence. FOB Middle East and FOB Singapore: 1978-85, Platts; 1985-89, Petroleum Market Intelligence. FOB Caribbean: 1980-85, FOB Venezuela (minimum government prices); Oil and Energy Trends--Annual Statistical Review," Energy Economics Research Ltd., May 1987; 1986-89, Petroleum Market Intelligence. US Gulf Coast (waterborne): Platt's.

ANNEX 4

SIMULATION MODEL FOR ESTIMATING ECONOMICS OF PETROCHEMICAL MANUFACTURE

A. Brief Description of Simulation Model

The model was set up using a lotus spreadsheet and was initially based on typical cost structures for the petrochemical industry as estimated by Stanford Research Institute and Chem Systems.

In step one the model selects a geographical location through a macro command. This allows to place the appropriate data ready for manipulation. The model then reads installation factors (estimated as described in Chapter 4) labor and utility costs as per pp2 of this annex, broader prices for feedstocks (ethane/propane, naphtha) as described in Annex 3.

Next, the model allows for selection of feedstock and size and reads the appropriate data for installed plant costs and material balances which are used to calculate feedstock or raw materials costs. With this information a production cost is estimated including all material and capital inputs, depreciation, interest payments and a return on equity based on the opportunity cost of capital.

In a next step, use is made of price projections to estimate revenues IRR and NPV of petrochemicals prepared as described below; to simplify, assumption has been made that the world price of the intermediates and products is the same independent of the location for all producers in Asia and in other regions. This obviously does not reflect the different situation between exporters and importers for the estimates of NPV's and IRR's but does not affect the production costs.

B. Pricing of Petrochemicals

Petrochemical prices have shown considerable short-term fluctuations in the past. The 1973 and 1979 energy price increases along with short-term speculative demand resulted in substantial polyolefin price increases in 1974 and 1980, while the economic recessions and the excess capacity depressed prices in 1978 and 1985-86. The combination of several factors such as (a) the substantial increases in worldwide capacity utilization, (b) the associated increases in producers' margins, (c) improvements in yield and technology, and (d) the fluctuations in feedstock costs, led to net price increases for most polyolefins in 1987/88 compared to the price levels of 1986.

Olefin and plastic prices are now expected to remain above the 1986/87 levels and then decrease as demand catches up with available capacity. By 1995, the product prices are expected gradually to level down as new production capacity is developed to balance demand.

Table A4-1 ITERATIVE STEPS INCLUDED IN THE SIMULATION MODEL

Step No.	Description	Remarks
1	Select Country or location	In Asia: Korea, India, China, Thailand, Malaysia, Indonesia. Outside Asia: US Gulf; W. Canada, S. Arabia.
2	Read Country Data	Installation factors; Labor/Utility costs; border prices for raw materials; utility and capital cost factors
3	Select configuration for basic feedstock plant and product plant technology and size.	Products covered: Ethyl- ene, LDPE, HDPE, PP, PS, PVC, ABS, SBR, DMT, ben- zene, each choice allows for a range of sizes and different technologies. Provides installed plant costs and material balance.
4	Calculate prodution costs	Estimates raw material labor, and utilities costs based on country data. Reads capital costs and estimated capital related charges, and return on equity
5	Read price projections and calculates economics of manufacture	Estimates revenues, calculates IRR and NPV, payment schedule and cash production costs
6	Provide data to downstream units	Estimates transfer prices for downstream manufacturing units. Feeds back information to step 3.

Table A4-2: ASSUMPTIONS USED IN THE ESTIMATES OF LABOR AND UTILITIES COSTS FOR THE MANUFACTURE OF PETROCHEMICALS

	KOREA	INDIA	CHINA	THAILAND	MALAYSIA	INDONESA
Operating Costs (US$/month)						
Labor						
Shift operators	600	300	45	300	300	300
Day workers	300	150	20	150	150	150
Technical	1,800	1,000	100	1,000	1,000	1,000
Maintenance	1,200	600	70	600	600	600
Clerical	1,000	500	60	500	500	500
Management	2,000	1,500	200	1,500	1,500	1,500
Average skilled (per year)			880			
Utilities (US¢/unit)						
Steam ($/ton)	30.12	11.68	4.27	30.12	30.12	10.63
Electricity (kWh)	3.80	7.00	3.80	3.80	3.80	2.70
Cooling water (m^3)	1.51	1.51	4.00	1.51	1.51	1.51
Processed water (m^3)	20.60	27.59	23.09	20.60	20.60	20.60
Inert gas (nm^3)	2.05	2.05	2.05	2.05	2.05	2.05
Natural gas (mcf)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

It is nevertheless, fairly difficult to forecast exact prices for petrochemicals. Ethylene prices for example are the result of a variety of market forces that include not only the demand/supply situation but also the feedstock prices, the spot price of naphtha or the cost of natural gas and the market price of cracker by-products such as propylene and butadiene, and indirectly the market price of other petroleum derivatives. Based on the past fluctuations of prices, and the low levels reached during 1984/85 a forecast has been made for future ethylene resins and other chemical prices, assuming that a new cycle of low prices will occur by 1995 when supply is expected to be substantially improved over the current levels. Still it is important to realize that prices for world traded basic commodities are subject to a multiplicity of factors, and therefore, the enclosed projections only reflect the likely magnitude of price trends related to future feedstock price increases as forecasted by the World Bank. Also, the estimates assume that changes in prices for downstream products will be correlated to changes in the world capacity factors and trends related to future feedstock price increases as forecasted by the World Bank. Also, the estimates assume that changes in prices for downstream products will be correlated to changes in the world capacity factors.

The prices projected are summarized in the table below. These assume that the 1995 prices will be similar to those experienced during 1985/86 and then will recover to a mid point between the 1988 and 1995 levels.

Table A4-3: MANUFACTURING GDP
(millions of currency units)

Country Base Year If not GDP Currency	KOREA 1980 US$	MALAYSIA 1983 Rp '000	INDONESIA 1978 M$ mln	INDIA 1980 Manu VA Rs bln	CHINA 1952 Index None	THAILAND 1972 VA baht
1978	10,259	7,189.0	5,107.5		4,980.41	2,174
1979	11,340	8,004.0	5,952.0		5,354.11	2,423
1980	11,214	8,742.0	7,304.4	216.40	5,643.50	2,717
1981	12,059	9,155.0	7,878.4	233.80	5,611.32	2,906
1982	12,559	9,668.0	7,973.1	249.10	6,186.81	2,921
1983	14,096	10,429.0	8,211.3	273.80	6,926.19	3,121
1984	16,188	11,711.0	9,770.3	292.90	7,509.92	3,606
1985	16,805	11,263.0	10,589.6	318.70	7,916.71	3,808
1986	19,737	12,111.0	11,161.5	347.20	8,521.73	4,160
1987	22,964	13,655.0	11,790.8	369.80	10,030.08	4,503
1988	25,490	15,567.0	12,435.6	391.70	11,634.89	5,043
1989	28,039	17,435.0	13,262.7	419.12	13,147.42	5,497
1990	30,843	19,527.0	14,186.9	448.46	14,856.59	5,965
1991	33,927	21,870.2	15,180.0	479.85	16,787.95	6,685
1992	36,098	24,494.7	16,242.6	513.44	18,970.38	7,153
1993	38,409	27,434.0	17,379.6	549.38	21,436.53	7,668
1994	40,867	30,726.1	18,596.1	587.84	24,233.28	8,220
1995	43,482	34,413.2	19,897.9	628.98	27,372.30	8,795

Table A4-4: ESTIMATE OF FUTURE PETROCHEMICAL PRICES /c
(for use in the comparative analysis of competitiveness)

	1985/86 previous low level (AVE)		1988	1995 (new low in price cycle)	2000
Ethylene	380	/a	639	430	500
Propylene	400	/a	430	400	430
Butadiene	350		400	350	400
Styrene	440		970	450	800
LDPE	650		990	700	1,000
HDPE	710	/b	1,080	750	1,000
PP	680		1,080	700	1,050
PS	710		1,280	850	1,050
SBR	930		1,170	900	1,100
Benzene	240	/c	400	250	400

/a Ave 1984/85.
/b Ave 1987.
/c Based on the past fluctuation of prices, a forecast was done, setting 1995 prices at a level comparable to the low prices reached during the period 1984/1986 in the US Gulf area, assuming therefore that by then supply is expected to have substantially improved over the current situation. For 1990, an interpolation has been done between the 1988 and 1995 levels. For the year 2000 the price level in 1990 has been repeated.

C. Ethylene Production Costs for Domestic Use in Asia Countries

Assuming equal sizes and capital costs (450,000 tpy and an installation factor of 1), i.e. purely from the standpoint of feedstock costs, and taking into account the impact of freight of products from the US, new crackers built for domestic use in Asia (such as those under construction or planning in India, Thailand, China and Korea) may remain competitiave with new US or Canadian ethane-based crackers as long as:

(a) If energy prices remain at their 1988 levels:

domestic ethane costs in Asia remain below US$4.3 per MMBUT (corresponding to US$2.8 per MMBUT in the US); and

domestic naphtha costs are less than US$180 per ton (actual prices in 1988 were US$145-155 per ton).

(b) If energy prices increase as projected by the Bank by 1995 and year 2000:

domestic ethane costs in Asia remain below US$5.5 per MMBTU (corresponding to US$3.5 per MMBTU in the US); and

domestic naphtha costs are less than US$200 per ton (projected naphtha prices are US$170-180 per ton by 1995 and $200-210 by year 2000).

Purely from the standpoint of feedstock costs, gas feedstock remain almost always preferable to naphtha feedstock whenever available (even when relatively expensive, such as in India). Whenever it is not available in sufficient quantities (as seems to be the case in China, Thailand and Korea), there appears to be a "window of opportunity" for naphtha-based crackers until the late nineties. However, this analysis is based on assumptions which are fairly reliable only until 1995, in particular regarding announced capacity expansion plans in the world to this date and projected energy prices. If substantial new export-oriented capacity were to be announced in later years in countries known to have still vast availability of associated gas (such as Iran, Algeria, Nigeria, Qatar, Venezuela or the Soviet Union), competitiveness of naphtha-based crackers in the world coming on stream in the mid-nineties would be significantly affected.

In such an uncertain environment, producers deciding to proceed with their plans to build naphtha-based crackers can reduce downside risks by taking the following actions:

Crackers for Domestic Consumption in Asia (China, India, Thailand, Korea)

- The ethane cost shown for 1988 and 1995 is the "affordable" cost of ethane in Asia which corresponds to the cost of ethane in the US.
- The naptha cost shown is the cost of naphtha yielding equivalent costs to the value of ethane specified above (price of naphtha for which the selection of an ethane-based on a naphtha-based cracker is indifferent).

Note: "Affordable" ethane cost based on a US$100 per ton product freight from the US (See Table 6.18).

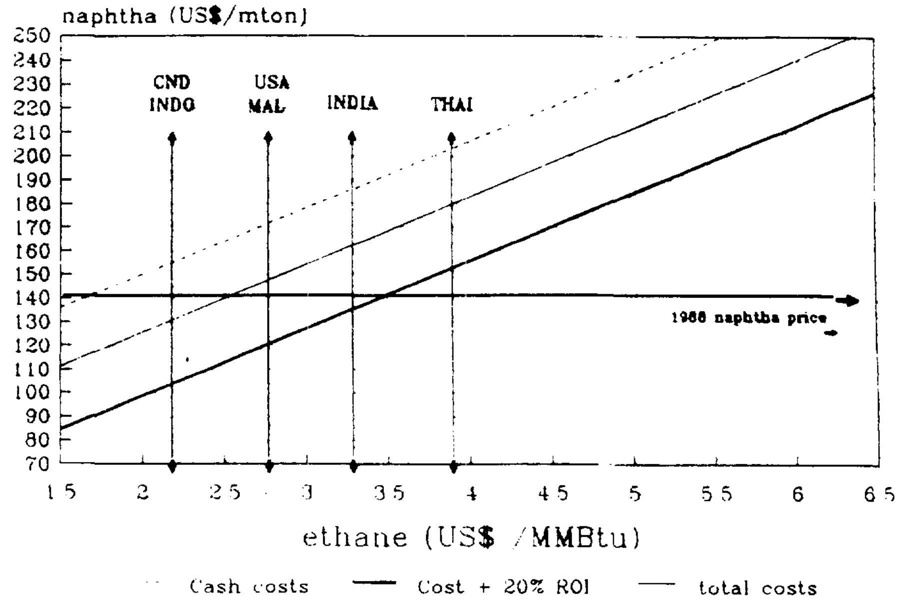
(a) limit capacity to the internal market and consistently operate the plants at high capacity utilization rates;

(b) construct plants that are at least as large as those of their competitors in the world;

(c) reduce investment costs to the maximum and reduce implementation periods (Governments can help by exempting capital goods from taxation and liberalizing the contracting industry) to achieve lower installation factors; and

(d) reduce financial vulnerability by adopting a strategy of downstream integration into high-value added products and away from products where ethylene costs are the most critical (for instance, dedicate

Fig A5.1 Values of Ethane and Naphtha Yielding Equivalent Costs



Per ton of ethylene-- 1988

as large a portion as feasible of the ethylene production to PVC or PS rather than polyethylenes).

EXPORT-ORIENTED CRACKERS IN ASIA (EXPORTS TO THE ASIA REGION)

- The ethane cost shown for 1988 and 1995 is the "affordable" cost of ethane in Asia which corresponds to the cost of ethane in the US.
- The naptha cost shown is the cost of naphtha yielding equivalent costs to the value of ethane specified above (price of naphtha for which the selection of an ethane-based on a naphtha-based cracker is indifferent).

Note: "Affordable ethane cost" based on a freight advantage of US$50 per ton of products (See Table 4.18)

Ethylene Production for Export

The previous graph shows that, in order to be competitive on the Asian export markets with product from the US, assuming everything else equal, ethane costs should not exceed US$3.5-4 per MMBTU in 1988 and US$4.5 per MMBTU by 1995 (only Indonesia and Malaysia will have a clear advantage in this respect). Naphtha-based crackers are unlikely to be competitive on the Asian export market since projected naphtha prices in Asia are expected to be above the limit under which naphtha-based crackers would be competitive with ethane-based crackers.

Fig A5.2 Naphtha Crackers in the USA

Margins on Ethylene Production

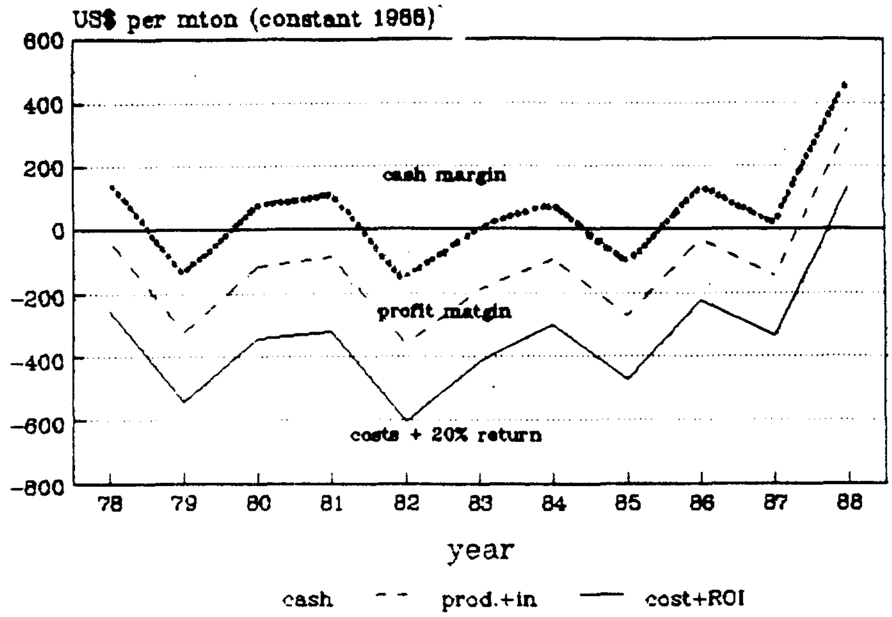
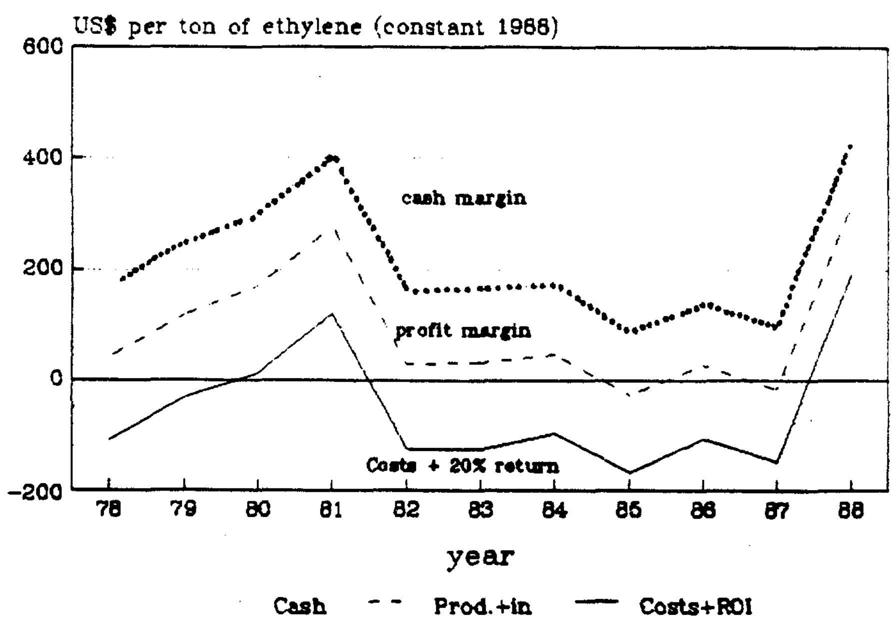


Fig A5.3 Ethane Crackers in the USA

Margins on ethylene production



ANNEX 5

STATISTICAL RESULTS OF THE SIMULATION MODEL

Table A5-1: RESULTS OF REGRESSION ANALYSIS BETWEEN REGIONAL GDP AND DEMAND FOR PETROCHEMICALS
(Demand = A + B (Industrial GDP Index))

	A	B	Standard error of B	R^2	/t/
Korea					
Ethylene	-353,612	66.134	2.267	0.993	29.169
Propylene	-51,407	35.382	2.570	0.969	13.770
Methanol	35,225	5.293	0.656	0.903	9.067
Benzene	-135,047	18.383	1.710	0.984	10.745
LDPE	-65,888	16.724	0.713	0.987	23.468
HDPE	-124,482	17.781	1.024	0.977	17.366
PP	-145,706	23.169	1.547	0.987	14.979
PVC	716,857	16.493	1.180	0.965	13.982
PS	-191,799	19.369	1.060	0.988	18.275
ABS	-66,128	7.269	0.312	0.987	23.32
SBR	9,524	3.906	0.723	0.864	5.400
India					
Ethylene	-188,237	2,072.680	247.578	0.909	8.372
Propylene	-49,912	578.028	76.540	0.891	7.552
Benzene	-93,386	724.639	218.247	0.739	3.203
LDPE	-2,545	385.798	49.397	0.897	7.810
HDPE /a	-84,939	566.834	52.366	0.974	10.824
PP	-42,164	255.098	21.219	0.954	12.011
PVC	-83,340	668.621	79.766	0.909	8.382
PS /a	-44,816	216.209	46.404	0.872	4.659
ABS	-2,439	16.811	2.631	0.891	6.391
PF /a	-2,005	861.735	180.613	0.952	4.771
PSF /a	-99,747	490.687	92.906	0.915	5.282
China					
Ethylene	-254,113	206.758	56.424	0.817	3.664
Propylene	-440,235	152.481	39.237	0.834	3.886
Butadiene	-128,463	41.171	8.129	0.895	5.065
Methanol	-134,489	76.918	7.778	0.980	9.889
Benzene	-172,621	92.639	24.221	0.830	3.825
Total PE	-943,095	249.201	39.322	0.889	6.338
PP	-292,707	94.845	34.850	0.712	2.722
PVC	2,581	72.735	8.146	0.941	8.929
PS	-357,827	62.901	20.376	0.761	3.087
SBR	-165,884	37.444	7.987	0.880	4.688
Total Poly.	-2,388,880	422.175	110.713	0.829	3.813

Table A5-1 (continued)

	A	B	Standard error of B	R^2	/t/
Thailand					
Ethylene	-73,801	62.044	15.181	0.770	4.087
Propylene	-43,674	33.731	5.601	0.879	6.023
Butadiene	-2,625	0.986	0.172	0.868	5.727
Benzene	-5,245	2.066	0.581	0.716	3.555
LDPE	-3,580	14.950	3.277	0.806	4.562
HDPE	-44,402	28.302	5.980	0.746	4.733
PP	-37,206	30.543	4.792	0.890	6.374
PVC	-47,537	30.361	6.366	0.820	4.769
PS /b	959	6.243	2.748	0.653	2.272
ABS /b	-1,886	1.032	0.172	0.835	5.986
SBR /b	-677	1.484	0.169	0.904	8.782
Malaysia					
Ethylene	-50,751	12.389	2.924	0.782	4.238
Propylene	-19,014	4.956	0.902	0.834	5.498
Butadiene	6,124	-0.314	0.118	0.586	-2.660
Methanol	-22,788	5.440	2.956	0.404	1.841
Benzene	-33,991	3.747	0.448	0.959	8.365
Total PE	-47,964	10.773	2.143	0.808	5.027
PP	-16,859	4.562	0.869	0.821	5.248
PVC	-50,276	6.935	0.764	0.942	9.076
PS	-39,527	5.387	0.378	0.971	14.235
SBR	7,884	-0.380	0.105	0.686	-3.623
Indonesia					
Ethylene	7,285	20.572	6.895	0.640	2.984
Propylene	14,220	16.263	5.050	0.675	3.221
Butadiene	-14,414	1.955	0.423	0.810	4.617
Methanol	-378,545	52.661	8.405	0.876	6.265
Benzene	5,839	1.362	0.207	0.896	5.477
Total PE	13,796	17.988	6.492	0.606	2.771
PP	13,543	15.489	4.809	0.675	3.221
PS	11,642	1.106	0.321	0.704	3.445
SBR	-19,799	2.686	0.582	0.810	4.618

/a Through the use of Hildreth Lu.
/b Through the use of Cochrane Orcutt
/c PR>/t/<0.001

Regressions were done through a PC version of EPS.

Table A5-2: UPPER AND LOWER LIMITS O. DEMAND OF SELECTED PETROCHEMICALS USING 95% CONFIDENCE INTERVAL

Year	COUNTRY Chemical	High case	Low case
1990	Ethylene	296,353	296,229
	Propylene	244,914	244,846
	Benzene	17,571	17,567
1995	Ethylene	471,937	471,813
	Propylene	340,271	340,305
	Benzene	23,372	23,414
	MALYSIA		
1990	Ethylene	191,180	191,156
	Propylene	115,795	115,785
	Benzene	107,163	107,155
1995	Ethylene	375,606	375,581
	Propylene	189,571	189,561
	Benzene	162,941	162,934
	INDONESIA		
1990	Ethylene	299,168	299,127
	Propylene	244,958	244,925
	Benzene	25,163	25,161
1995	Ethylene	416,658	416,617
	Propylene	337,836	337,803
	Benzene	32,942	32,939
	KOREA		
1990	Ethylene	1,686,224	1,686,091
	Propylene	1,142,730	1,142,659
	Benzene	431,961	431,924
1995	Ethylene	2,522,092	2,521,960
	Propylene	1,589,923	1,589,852
	Benzene	664,305	664,268
	INDIA		
1990	Ethylene	743,349	739,204
	Propylene	209,888	208,732
	Benzene	419,056	417,658

Table 5.2 (continued)

Year	COUNTRY Chemical	High case	Low case
	INDIA (continued)		
1995	Ethylene	1,117,510	1,113,365
	Propylene	314,234	313,078
	Benzene	549,869	548,471
	CHINA		
1990	Ethylene	2,817,792	2,817,378
	Propylene	1,825,250	1,824,945
	Benzene	1,203,762	1,203,577
1995	Ethylene	5,405,536	5,405,122
	Propylene	3,733,673	3,733,368
	Benzene	2,363,214	2,363,029

ANNEX 6

COMPREHENSIVE LIST OF PLANT CAPACITIES

Table A6-1: ASTIF ASIA CHEMICAL PRODUCTION SUMMARY TABLE (Capacity through 1989)

Chemical	India	Korea	Indonesia	Malaysia	Thailand	China	Taiwan	Japan
Ethylene	213,000	505,000	0	0	0	1,960,000	953,000	4,295,000
Propylene	96,000	268,000	0	0	0	606,000	478,000	2,510,000
Butadiene	0	94,000	0	0	0	506,500	128,000	349,000
Benzene	89,000	409,000	0	0	0	428,000	0	0
Methanol	0	330,000	330,000	660,000	0	629,000	192,000	891
LDPE	128,000	292,000	0	0	174,000	402,000	240,000	0
HDPE	50,000	280,000	0	0	0	285,000	200,000	900,000
PP	30,000	660,000	10,000	0	0	165,000	220,000	0
PS	2,200	424,000	21,300	30,000	23,000	10,000	223,200	1,332
ABS	7,400	190,000	0	0	0	10,000	185,000	562,400
Polyester	86,600	349,626	123,000	40,800	77,000	615,000	0	15,000
PVC	157,000	540,000	94,000	39,000	54,000	80,000	940,000	1,707,000
SBR	33,000	150,000	0	0	0	201,000	108,000	679,000

Table A6-2: ASTIF ASIA CHEMICAL PRODUCTION SUMMARY TABLE (Capacity through 2000)

Chemical	India	Korea	Indonesia	Malaysia	Thailand	China	Taiwan	Japan /a
Ethylene	3,311,000	3,505,000	375,000	500,000	564,500	2,995,000	1,906,000	4,295,000
Propylene	441,000	1,817,000	322,000	200,000	269,480	606,000	478,000	2,510,000
Butadiene	115,000	538,000	0	0	16,810	594,000	128,000	349,000
Benzene	209,000	854,000	528,000	0	121,000	608,000	0	0
Methanol	228,200	330,000	330,000	660,000	0	629,000	192,000	891
LDPE	308,000	812,300	0	0	399,000	647,000	240,000	0
LLDPE	130,000	113,000	0	0	50,000	140,000	120,000	0
HDPE	245,000	710,000	420,000	160,000	290,000	425,000	200,000	900,000
PP	315,000	1,210,000	520,000	240,000	340,000	430,000	280,000	0
PS	117,000	564,000	61,300	30,000	171,000	104,500	223,200	1,332
ABS	17,400	242,000	4,500	0	40,000	10,000	185,000	562,400
Polyester	247,100	564,526	283,000	40,800	213,000	1,074,600	0	15,000
PVC	257,000	610,000	164,000	119,000	249,000	917,500	1,160,000	1,707,000
SBR	33,000	182,000	50,000	0	13,000	281,000	108,000	679,000

/a 1989 data included to facilitate comparison.

* ASTIF ASIA CHEMICAL PRODUCTION COMPREHENSIVE LIST *

COMPANY	LOCATION	CAPACITY	YEAR ONSTREAM	STATUS	EXPECTED COMPLETION
	COUNTRY = INDIA		CHEMICAL = ETHYLENE		
Chems & Plastics India	Mettur Dam	19000	0	0	0
Indian Petrochemical	Baroda	130000	1971	0	0
NOCIL	THANE	60000	1968	0	0
Synthetics & Chemicals	Bareilly	4000	0	0	0
MGCC	NAGOTHANE	300000	0	C	1990
MGCC	NAGOTHANE	100000	0	C	1992
IPCL	BARODA	73000	0	P	2000
RELIANCE	HAZIRA	320000	0	P	2000
	VIJAYPUR	300000	0	P	2000
OSWAL AGRO	RISHRA & BOMBAY	100000	0	C	1990
HALDIA PETROCHEMICALS	HALDIA	150000	0	P	2000
NOCIL		235000	0	P	2000
NATIONAL PETROCHEM CO.	KOYALI	100000	0	C	1989
AURIYA GAS CRACKER	AURIYA, UP	300000	0	P	2000
VIZAG PETROCHEMICALS	VIZAG (AP)	250000	0	P	2000
MANGALORE PETROCHEM.	MANGALORE	250000	0	P	2000
IPCL	BARODA	170000	0	P	2000
LINDE EOU PROJECT	MADRAS	450000	0	P	2000
	COUNTRY = INDIA		CHEMICAL = PROPYLENE		
Hindustan Organic	Cochin	29000	1972	0	0
IPCL	Baroda	81000	0	P	2000
IPCL	Baroda	30000	1972	0	0
NOCIL	Bombay	37000	1968	0	0
MGCC	NAGOTHANE	30000	0	C	1990
MADRAS RFY LTD	MADRAS	17000	0	C	1989
IPCL	NAGOTHANE	12000	0	C	1992
NATIONAL PETROCHEM CO.	KOYALI	60000	0	C	1989
RELIANCE	HAZIRA	145000	0	P	2000
	COUNTRY = INDIA		CHEMICAL = BUTADIENE		
IPCL	BARODA	22000	0	P	2000
MGCC	N.A.	10000	0	P	2000
MGCC	N.A.	1000	0	P	2000
SYNTHETIC & CHEMICALS	N.A.	12000	0	P	2000
S & C	BAREILLY, UP	14000	0	C	1989
NOCIL	THANE	7000	0	P	2000
RELIANCE	HAZIRA	49000	0	P	2000
	COUNTRY = INDIA		CHEMICAL = BENZENE		
Durgapur Projects	Durgapur	5300	0	0	0

* ASTIF ASIA CHEMICAL PRODUCTION COMPREHENSIVE LIST *

COMPANY	LOCATION	CAPACITY	YEAR ONSTREAM	STATUS	EXPECTED COMPLETION
Fertilizer Corp	Sindri	1700	0	0	0
Hindustan Steel	Rourkela	10000	0	0	0
Indian Iron & Steel	Burnpur	2000	0	0	0
Indian Oil	Baroda	45000	0	0	0
Indian Petrochemical	Baroda	23600	0	0	0
NOCIL	Bombay	17000	0	0	0
Tata Iron & Steel	Jamshedpur	2400	0	0	0
Union Carbide India	Trombay	6000	0	0	0
MADRAS AROMATIC COMPLX	MADRAS	120000	0	P	2000
BHARAT PETROLEUM	BOMBAY	98300	1985	0	0
COCHIN REFINERIES	COCHIN	87200	0	P	2000
BOKARO STEEL	BOKARO	30000	0	0	0
BHILAI STEEL	BHILAI	13000	0	0	0
	COUNTRY = INDIA	CHEMICAL = METHANOL			
BONGAIGAON RFY&PETROCH	BONGAIGAON	2700	0	P	2000
GUJARAT NARMADA VALLEY	BHARUCH	109500	0	C	1990
DEEPAK FERT & CHEM.		109500	0	C	1990
ASSAM IND. DEV. CORP.	MARON-LAKWA	6500	0	P	2000
	COUNTRY = INDIA	CHEMICAL = LDPE			
Indian Explosives	Rishra	16000	0	0	0
IPCL	NAGOTHANE	80000	0	C	1990
RELIANCE	HAZIRA	100000	0	P	2000
IEL	CALCUTTA	12000	0	0	0
IPCL	BARODA	80000	1972	0	0
UCIL	BOMBAY	20000	0	0	1965
	COUNTRY = INDIA	CHEMICAL = LLDPE			
IPCL	NAGOTHANE	80000	0	C	1990
Reliance Industries	Hazira	50000	0	C	1992
	COUNTRY = INDIA	CHEMICAL = HDPE			
NOCIL	THANEY	50000	0	0	0
IPCL	NAGOTHANE	55000	0	C	1990
RELIANCE	HAZIRA	60000	0	C	1991
HALDIA PETROCHEM	HALDIA	80000	0	P	2000
	COUNTRY = INDIA	CHEMICAL = PP			

* ASTIF ASIA CHEMICAL PRODUCTION COMPREHENSIVE LIST*

COMPANY	LOCATION	CAPACITY	YEAR ONSTREAM	STATUS	EXPECTED COMPLETION
IPCL	Baroda	30000	1971	O	0
Haldia Petrochem	HALDIA	70000	0	C	1991
MGCC	Nagothane	60000	0	C	1989
n.a.	Mathura	15000	0	P	2000
IPCL	VADODARA	30000	0	C	1992
PICUP	UP	50000	0	P	2000
RELIANCE	HAZIRA	60000	0	C	1992

COUNTRY = INDIA CHEMICAL = PS

COMPANY	LOCATION	CAPACITY	YEAR ONSTREAM	STATUS	EXPECTED COMPLETION
Hindustan Polymers	Visakhapatnam	10000	0	O	0
Polychem	Bombay	10000	0	O	0
BASF INDIA	N.A.	15000	0	P	2000
MCDOWELL & CO. LTD	VISAKHAPATNAM	2000	1989	O	0
RELIANCE	HAZIRA	80000	0	P	2000

COUNTRY = INDIA CHEMICAL = ABS

COMPANY	LOCATION	CAPACITY	YEAR ONSTREAM	STATUS	EXPECTED COMPLETION
ABS Plastics	Baroda	2000	0	O	0
Polychem	Koyali	2000	0	O	0
ABS Plastics	NAN DESARI	5000	0	P	2000
MCDOWELL & CO. LTD	VISAKHAPATNAM	5000	0	C	1990
GUJBINIL	ANKLESHWAR	2200	0	O	0
S & C	BAREILLY	1200	0	O	0

COUNTRY = INDIA CHEMICAL = POLYESTER

COMPANY	LOCATION	CAPACITY	YEAR ONSTREAM	STATUS	EXPECTED COMPLETION
Ahmedabad Manuf	Baroda	8000	0	O	0
Baroda Rayon	Surat	1000	0	O	0
Century Enka	Pune	0	0	O	0
Chemicals & Fibers	Bombay	10000	0	O	0
Garware Nylons	Pune	1000	0	O	0
Indian Organic Chems	Madras	12000	0	O	0
J.K. Synthetics	Kota	7000	0	O	0
Modipon	Ghaziabad	1000	0	O	0
Nirlon Syn Fibers	Bombay	4000	0	O	0
Petrofils	Baroda	7000	0	O	0
Shree Synthetics	Ujjain	1000	0	O	0
Swadeshi Polytex	Ghaziabad	8000	0	O	0
Orkay Silk Mills	Patalganga	6600	0	O	0
Indian Explosives	Thana	20000	0	O	0
PRAG BOSIMI SYNTHETICS	ASSAM	22000	0	C	1989

*** ASTIF ASIA CHEMICAL PRODUCTION COMPREHENSIVE LIST ***

COMPANY	LOCATION	CAPACITY	YEAR ONSTREAM	STATUS	EXPECTED COMPLETION
Orkay Silk Mills	Patalganga	10000	0	P	2000
Bongaigaon Refinery	Bongaigaon	30000	0	P	2000
Reliance Textiles	Patalganga	45000	0	P	2000
J.K. Synthetics	Kota	7000	0	P	2000
Ahmedabad Mfg	Baroda	6500	0	P	2000
DCL POLYESTER LTD	NAGPUR	15000	0	C	1989
PUNJAB POLYFIBERS LTD	HOSHIAPUR	25000	0	C	1989
	COUNTRY = INDIA	CHEMICAL = PVC			
Ahmedabad Manuf	Bombay	20000	0	0	0
Chems & Plastics	Mettur Dam	20000	0	0	0
NOCIL	Bombay	20000	0	0	0
Shriram Chem Ind	Kota	20000	0	0	0
IPCL	VADODARA	55000	0	0	0
CALICO (ILAC)	BOMBAY	6000	0	0	0
PRC	TUTICORIN	16000	0	0	0
RELIANCE	HAZIRA	100000	0	C	1991
	COUNTRY = INDIA	CHEMICAL = SBR			
Synthetics & Chems	Bareilly	33000	0	0	0
	COUNTRY = KOREA	CHEMICAL = ETHYLENE			
Daelim Industrial	YEOCHON	350000	1979	0	0
Yukong Ltd	Ulsan	155000	1972	0	0
Lucky Chemical	Yeochon	350000	0	C	1991
HYUNDAI PETROCHEMICAL	DAESAN	350000	0	P	2000
Yukong Ltd	Ulsan	400000	0	C	1989
Korea Petrochem Ind	Ulsan	250000	0	P	2000
HANYANG CHEMICAL	Yeochon	350000	0	P	2000
Daelim Industrial	YEOCHON	250000	0	C	1989
SAMSUNG	N.A.	350000	0	P	2000
KUMHO PETROCHEMICAL	N.A.	350000	0	P	2000
HONAM PETROCHEMICAL	N.A.	350000	0	P	2000
	COUNTRY = KOREA	CHEMICAL = PROPYLENE			
Yukong	Ulsan	81000	1972	0	0
Yukong	Ulsan	212000	0	C	1989
DAELIM INDUSTRIAL CO.	YEOCHON	187000	1979	0	0

* ASTIF ASIA CHEMICAL PRODUCTION COMPREHENSIVE LIST *

COMPANY	LOCATION	CAPACITY	YEAR ONSTREAM	STATUS	EXPECTED COMPLETION
LUCKY PETROCHEMICAL	YEOCHON	164000	0	C	1991
DAELIM INDUSTRIAL CO.	YEOCHON	145000	0	C	1989
HYUNDAI	DESAN	175000	0	P	2000
SAMSUNG	N.A.	175000	0	P	2000
KUMHO	N.A.	190000	0	P	2000
HONAM PETROCHEMICAL	N.A.	190000	0	P	2000
HANYANG CHEMICAL	N.A.	150000	0	P	2000
KOREA PETROCHEMICAL	N.A.	148000	0	P	2000
	COUNTRY = KOREA	CHEMICAL = BUTADIENE			
Yukong	Ulsan	24000	1972	O	0
Yukong	Ulsan	212000	0	C	1989
KOREA KUMHO PETROCHEM	Yeochon	70000	1978	O	0
KOREA KUMHO PETROCHEM.	YEOCHON	35000	0	C	1989
HYUNDAI	DESAN	51000	0	P	2000
SAMSUNG	N.A.	45000	0	P	2000
KUMHO PETROCHEMICAL	N.A.	56000	0	P	2000
HANYANG CHEMICAL	N.A.	45000	0	P	2000
	COUNTRY = KOREA	CHEMICAL = BENZENE			
Korea Steel	Pohang	30000	1976	O	0
Yukong	Ulsan	194000	1970	O	0
HONAM OIL REFINERY CO.	YEOCHON	80000	0	C	1989
Yukong	Ulsan	73000	0	C	1989
SSANGYONG OIL REFINING	ONSAN	45000	0	C	1989
KOHAP CHEMICAL CORP.	Ulsan	30000	1986	O	0
DAELIM INDUSTRIAL CO.	YEOCHON	85000	1979	O	0
DAELIM INDUSTRIAL CO.	YEOCHON	66000	0	C	1989
KOHAP CHEMICAL CORP.	Ulsan	46000	1989	C	0
HONAM OIL	N.A.	100000	0	C	1991
KOREA KUMHO PETROCHEM.	YEOCHAN	70000	1979	O	0
KOREA KUMHO PETROCHEM.	YEOCHAN	35000	0	C	1989
	COUNTRY = KOREA	CHEMICAL = METHANOL			
Taesung Methanol	YEOCHON	330000	1976	O	0
	COUNTRY = KOREA	CHEMICAL = LDPE			
HANYANG CHEMICAL	Ulsan	60000	1972	O	0
Hanyang Chemical	YEOCHON	210000	1979	O	0

* ASTIF ASIA CHEMICAL PRODUCTION COMPREHENSIVE LIST *

COMPANY	LOCATION	CAPACITY	YEAR ONSTREAM	STATUS	EXPECTED COMPLETION
Hanyang Chemical	YEOCHON	22000	0	O	1989
Yukong	ULSAN	80000	0	C	1989
HAN KOOK FIBRES CORP.	GUMI CITY	200300	0	C	1990
LUCKY CHEMICAL	YEOCHON	100000	0	C	1989
SAMSUNG	N.A.	140000	0	P	2000
	COUNTRY = KOREA		CHEMICAL = LLDPE		
HANYANG CHEMICAL	Yeochon	113000	0	P	2000
	COUNTRY = KOREA		CHEMICAL = HDPE		
Honam Petrochemical	YEOCHON	90000	1979	O	0
Korea Petrochemical	Ulsan	150000	1976	O	0
HONAM PETROCHEMICAL	YEOCHON	40000	1988	O	0
DAELIM INDUSTRIAL	YEOCHON	120000	0	C	1989
YUKONG	ULSAN	40000	0	C	1989
SAMSUNG	N.A.	120000	0	P	2000
KUMHO	N.A.	150000	0	P	2000
	COUNTRY = KOREA		CHEMICAL = PP		
Yukong	Ulsan	80000	0	C	1989
Honam Petrochemical	Yeochon	80000	0	O	1988
SAMSUNG	N.A.	170000	0	P	2000
KOREA PETROCHEMICAL	ULSAN	280000	1972	O	0
KOREA PETROCHEMICAL	ULSAN	70000	0	O	1988
HONAM PETROCHEMICAL	YEOCHON	110000	1979	O	0
HONAM OIL REFINING CO.	YEOCHON	120000	1987	O	0
DONGYANG	YEOCHON	80000	0	C	1990
HANYANG CHEMICAL	YEOCHON	120000	0	P	2000
KUMHO	N.A.	100000	0	P	2000
	COUNTRY = KOREA		CHEMICAL = PS		
Hannam Chemical	Ulsan	146000	1973	O	0
Hyosung BASF	Ulsan	60000	1982	O	0
Lucky Chemical	Yeo-Chon	50000	1984	O	0
Lucky Chemical	Yeochon	45000	1989	O	0
CHEIL WOOL TEXTILE CO.	YEOCHON	90000	0	C	1989
HYOSUNG BASF	Ulsan	75000	1988	O	0
SHIN-A CHEMICAL	ANYANG	48000	1973	O	0
DONGBU PETRO	ULSAN	50000	0	C	1988

* ASTIF ASIA CHEMICAL PRODUCTION COMPREHENSIVE LIST *

COMPANY	LOCATION	CAPACITY	YEAR ONSTREAM	STATUS	EXPECTED COMPLETION
	COUNTRY = KOREA	CHEMICAL = ABS			
Hannam Chemical	Ulsan	40000	1973	0	0
Lucky Chemical	YEOCHON	135000	1978	0	0
SHIN-A CHEMICAL	ANYANG	15000	1984	0	0
HYOSUNG BASF	ULSAN	22000	0	C	1989
CHEIL WOOL TEXTILE CO.	YEOCHON	30000	0	C	1989
	COUNTRY = KOREA	CHEMICAL = POLYESTER			
Cheil Syn Textile	Gumi	24820	0	0	0
Dae Han Synthetic	Pusan	46720	0	0	0
Dae Sung Woold	n.a.	0	0	0	0
Jeil Chemical Fiber	Seoul	2190	0	0	0
Kohap	Shihung	34310	0	0	0
Kolon (Polyester)	Gumi	71905	0	0	0
Sam Kwang Moolsan	Ki Jank	2000	0	0	0
Sam Yang	Chonju	41245	0	0	0
Sunkyong	Suwon	45990	0	0	0
Tong Yang Polyester	Ulsan	71905	0	0	0
Tong Yank Nylon	n.a.	8541	0	0	0
Zion Synthetic Fiber	Seoul	0	0	0	0
HAN KOOK FIBERS	GUMI CITY	200300	0	C	1990
TONG KOOK	N.A.	14600	0	0	0
	COUNTRY = KOREA	CHEMICAL = PVC			
HANYANG CHEMICAL	ULSAN & ETC.	250000	0	0	0
Lucky Chemical	YEOCHON	280000	1976	0	0
HANYANG CHEMICAL CORP.	Ulsan	10000	0	0	1989
HANYANG CHEMICAL CORP.	YEOCHON	70000	0	C	1990
	COUNTRY = KOREA	CHEMICAL = SBR			
KOREA KUMHO PETROCHEM	Ulsan	20000	1983	0	0
KOREA KUMHO PETROCHEM	Ulsan	130000	1973	0	0
KOREA KUMHO PETROCHEM	ULSAN	20000	0	C	1989
ULSAN PACIFIC CHEMICAL	ULSAN	12000	0	C	1989
	COUNTRY = INDONESIA	CHEMICAL = ETHYLENE			

* ASTIF ASIA CHEMICAL PRODUCTION COMPREHENSIVE LIST *

COMPANY	LOCATION	CAPACITY	YEAR ONSTREAM	STATUS	EXPECTED COMPLETION
SHELL	CILACAP	375000	0	P	2000
	COUNTRY = INDONESIA	CHEMICAL = PROPYLENE			
Pertamina	Plaju	100000	0	C	1991
MITSUBISHI	CILACAP	222000	0	P	2000
	COUNTRY = INDONESIA	CHEMICAL = BUTADIENE			
	COUNTRY = INDONESIA	CHEMICAL = BENZENE			
n.a.	Arun, Aceh	405000	0	P	2000
PERTAMINA	CILACAP	123000	0	C	1990
	COUNTRY = INDONESIA	CHEMICAL = METHANOL			
PERTAMINA	PULAU BUNYU	330000	0	0	0
	COUNTRY = INDONESIA	CHEMICAL = LDPE			
	COUNTRY = INDONESIA	CHEMICAL = LLDPE			
	COUNTRY = INDONESIA	CHEMICAL = HDPE			
PT ARSETO/BRIT PETRO	N.A.	120000	0	C	0
N.A.	CILACAP	300000	0	C	0
	COUNTRY = INDONESIA	CHEMICAL = PP			
PN PERTAMINA	Plaju	10000	0	0	0
PT MEGA POLYMER	Tangerang	125000	0	C	1991
PT ASEAN POLYMER	Tangerang	100000	0	C	1991
PT TRI POLYTA INDO	Tangerang	160000	0	C	1991
N.A.	CILACAP	125000	0	P	2000
	COUNTRY = INDONESIA	CHEMICAL = PS			
PT PACIFIC PLASTIK	Serang	20000	0	C	0
PT Polychem Lindo	MERAK	21500	0	0	0
PT BENTALA AGUNG	PALEMBANG	19800	0	0	0

* ASTIF ASIA CHEMICAL PRODUCTION COMPREHENSIVE LIST *

COMPANY	LOCATION	CAPACITY	YEAR ONSTREAM	STATUS	EXPECTED COMPLETION
	COUNTRY = INDONESIA	CHEMICAL = ABS			
PT Polychem Lindo	MERAK	4500	0	C	1989
	COUNTRY = INDONESIA	CHEMICAL = POLYESTER			
Indonesia Toray	Pasar-Baru	14000	0	0	0
Kuraray	Pasar-Baru	14000	0	0	0
Sulinda	Jakarta	5000	0	0	0
Teijin Indonesia	Tangerang	42000	0	0	0
Texmaco	Malang	12000	0	0	0
Uasinta	Tangerang	16000	0	0	0
Tri Rempoa	Banaran	20000	0	0	0
Sulinda	Jakarta	40000	0	P	2000
PT YASINTA	TANGERANG	120000	0	C	1990
	COUNTRY = INDONESIA	CHEMICAL = PVC			
PT EASTERN POLYMER	Jakarta	36000	0	0	0
PT STATOMER	Merak	58000	0	0	0
PT ASAHIMAS SUBENTRA	MERAK, W. JAVA	70000	0	C	1989
	COUNTRY = INDONESIA	CHEMICAL = SBR			
SUKSES BINA SELARAS	Bekasi	25000	0	C	1990
PT INDOFIRST	CIKAMPEK	25000	0	C	1989
	COUNTRY = MALAYSIA	CHEMICAL = ETHYLENE			
N.A.	KERTIH	300000	0	P	2000
ASIA PACIFIC PETROCHEM	KERTIH	200000	0	P	2000
	COUNTRY = MALAYSIA	CHEMICAL = PROPYLENE			
N.A.	n.a.	100000	0	P	2000
ASIA PACIFIC CHEMICALS	KERTIH	100000	0	P	2000
	COUNTRY = MALAYSIA	CHEMICAL = BUTADIENE			
	COUNTRY = MALAYSIA	CHEMICAL = BENZENE			

*** ASTIF ASIA CHEMICAL PRODUCTION COMPREHENSIVE LIST ***

COMPANY	LOCATION	CAPACITY	YEAR ONSTREAM	STATUS	EXPECTED COMPLETION
	COUNTRY = MALAYSIA	CHEMICAL = METHANOL			
SABAH GAS	N.A.	660000	0	0	0
	COUNTRY = MALAYSIA	CHEMICAL = LDPE			
	COUNTRY = MALAYSIA	CHEMICAL = LLDPE			
	COUNTRY = MALAYSIA	CHEMICAL = HDPE			
ASIA PACIFIC CHEMICALS	N.A.	100000	0	P	2000
NPC II	N.A	60000	0	P	2000
	COUNTRY = MALAYSIA	CHEMICAL = PP			
Petronas	KUANTAN	80000	0	P	2000
ASIA PACIFIC POLYMER	N.A.	80000	0	P	2000
THAI PETROCHEMICAL	N.A	80000	0	C	1990
	COUNTRY = MALAYSIA	CHEMICAL = PS			
Petrochems Malaysia	Tampoi	24000	0	0	0
POLYSTYRENE SDN BHD	N.A.	6000	0	0	0
	COUNTRY = MALAYSIA	CHEMICAL = ABS			
	COUNTRY = MALAYSIA	CHEMICAL = POLYESTER			
Penfibre	Penang	40800	0	0	0
	COUNTRY = MALAYSIA	CHEMICAL = PVC			
MALAYAN ELECTROCHEM	Penang	12000	0	0	0
INDUSTRIAL RESINS	Johore Bahru	27000	0	0	0
NORSECHEM LAMINATES	TERENGGANU (?)	20000	0	P	2000
THAI PLASTICS	RAYONG	60000	0	P	2000
	COUNTRY = MALAYSIA	CHEMICAL = SBR			

* ASTIF ASIA CHEMICAL PRODUCTION COMPREHENSIVE LIST *

COMPANY	LOCATION	CAPACITY	YEAR ONSTREAM	STATUS	EXPECTED COMPLETION
	COUNTRY = THAILAND	CHEMICAL = ETHYLENE			
Nat'l Petrochemical	Mab Ta Put	315000	0	C	1989
NPC II		249500	0	P	2000
	COUNTRY = THAILAND	CHEMICAL = PROPYLENE			
Nat'l Petrochemical	Mab Ta Put	105000	0	C	1989
NPC II		164480	0	P	2000
	COUNTRY = THAILAND	CHEMICAL = BUTADIENE			
NPC II		16810	0	P	2000
	COUNTRY = THAILAND	CHEMICAL = BENZENE			
NPC II		121000	0	P	2000
	COUNTRY = THAILAND	CHEMICAL = METHANOL			
	COUNTRY = THAILAND	CHEMICAL = LDPE			
Thai Petrochemical	Rayong	100000	0	0	0
Thai Petrochemical	Rayong	74000	0	0	0
THAI PETROCHEMICAL	RAYONG	60000	0	C	1989
THAI PETROCHEMICAL CO.	MAP-TA PHUT	65000	0	C	1989
NATIONAL PETROCHEMICAL	MAP-TA PHUT	100000	0	C	1989
	COUNTRY = THAILAND	CHEMICAL = LLDPE			
THAI POLYETHYLENE	Map Ta Phut	50000	0	C	1989
	COUNTRY = THAILAND	CHEMICAL = HDPE			
Thai Polyethylene	Mab Ta Put	60000	0	C	1989
THAI PETROCHEMICAL	Mab Ta Put	60000	0	C	1989
NATIONAL PETROCHEMICAL	Mab Ta Put	110000	0	C	1989
NPC II	N.A.	60000	0	P	2000

*** ASTIF ASIA CHEMICAL PRODUCTION COMPREHENSIVE LIST ***

COMPANY	LOCATION	CAPACITY	YEAR ONSTREAM	STATUS	EXPECTED COMPLETION
	COUNTRY = THAILAND	CHEMICAL = PP			
HMC Polymer	Rayong	100000	0	C	1989
NPC II		160000	0	P	2000
THAI PETROCHEMICAL	N.A.	80000	0	C	1990
	COUNTRY = THAILAND	CHEMICAL = PS			
Pacific Plastics	Samut Prakan	23000	0	O	0
SRITHEPTHAI	BANGKOK	10000	0	C	1989
TPI	n.a.	29000	0	P	2000
NPC II		109000	0	P	2000
	COUNTRY = THAILAND	CHEMICAL = ABS			
THAI PETROCHEMICAL	RAYONG	10000	0	C	1990
NPC II		30000	0	P	2000
	COUNTRY = THAILAND	CHEMICAL = POLYESTER			
Oriental Fibre	Bangkok	2000	0	O	0
Toray Nylon Thai	Bangkok	7000	0	O	0
Thai Melon	Pathumthani	24000	0	O	0
Teijin Polyester	Pathumthani	44000	0	O	0
Teijin Polyester	n.a.	24000	0	P	2000
Thai Melon	n.a.	33000	0	P	2000
Toray Nylon Thai	n.a.	5000	0	P	2000
Tumtex	n.a.	36000	0	P	2000
Thai Nippon	n.a.	28000	0	P	2000
Other	n.a.	10000	0	P	2000
	COUNTRY = THAILAND	CHEMICAL = PVC			
Taplaco	Bangkok	54000	0	O	0
THAI PLASTICS	MAB TA PHUT	135000	0	C	1989
THAI PLASTICS	RAYONG	60000	0	P	2000
	COUNTRY = THAILAND	CHEMICAL = SBR			
Siam Cement	n.a.	13000	0	P	2000
	COUNTRY = CHINA	CHEMICAL = ETHYLENE			

* ASTIF ASIA CHEMICAL PRODUCTION COMPREHENSIVE LIST *

COMPANY	LOCATION	CAPACITY	YEAR ONSTREAM	STATUS	EXPECTED COMPLETION
State Complex	YANGSHAN	300000	1988	O	0
State Complex	Jilin	115000	1982	O	0
State Complex	Jinshan	120000	0	O	1989
State Complex	GAOQUIAO	20000	1987	O	0
State Complex	Liaoyang	73000	0	O	0
CNTIC	YANGZI-JIANGSU	300000	0	P	2000
CNTIC	Panjin	130000	0	C	1990
CNTIC	DAQING	300000	0	O	0
CNTIC	QILU-SHANDONG	300000	1987	O	0
SHANGHAI PETROCHEM	JINSHAN	300000	0	C	1991
STATE COMPLEX	BEJING-YANSHAN	300000	1989	O	0
LANZHOU CHEMICAL IND	GANZU-LANZHOU	72000	0	O	0
STATE COMPLEX	NANJING	60000	0	O	0
CNTIC	YANGZI	300000	0	O	0
STATE COMPLEX	LIAOYANG	45000	0	P	2000
ZHONG YUAN PETRO CORP.	PUJANG	140000	0	C	1992
STATE COMPLEX	FUSHUN	120000	0	C	1989

COUNTRY = CHINA CHEMICAL = PROPYLENE

COMPANY	LOCATION	CAPACITY	YEAR ONSTREAM	STATUS	EXPECTED COMPLETION
State Complex	Daqing	80000	0	O	0
State Complex	YANGSHAN	130000	0	O	0
State Complex	Jilin	50000	0	O	0
State Complex	Jinshan	50000	0	O	0
State Complex	Lanzhou	20000	0	O	0
State Complex	Liaoyang	35000	0	O	0
CNTIC	QUILO	60000	0	O	0
STATE COMPLEX	YANGZI	140000	0	O	0
STATE COMPLEX	NANJING	28000	0	O	0
STATE COMPLEX	GAOQUIAO	13000	0	O	0

COUNTRY = CHINA CHEMICAL = BUTADIENE

COMPANY	LOCATION	CAPACITY	YEAR ONSTREAM	STATUS	EXPECTED COMPLETION
STATE COMPLEX	YANGSHAN	215000	0	O	0
CNTIC	QUILU	70000	0	O	0
STATE COMPLEX	YANGSHAN	45000	0	O	0
STATE COMPLEX	PANJING	87500	0	P	2000
STATE COMPLEX	LIAOYANG	45000	1975	O	0
STATE COMPLEX	JILIN	60000	1982	O	0
STATE COMPLEX	GAOQUIAO	21500	0	O	0
STATE COMPLEX	LANZHOU	50000	0	O	0

* ASTIF ASIA CHEMICAL PRODUCTION COMPREHENSIVE LIST *

COMPANY	LOCATION	CAPACITY	YEAR ONSTREAM	STATUS	EXPECTED COMPLETION
	COUNTRY = CHINA		CHEMICAL = BENZENE		
STATE COMPLEX	BEIJING-YANSHAN	100000	0	0	0
STATE COMPLEX	TIANJIN	20000	0	0	0
STATE COMPLEX	LIAOYANG	163000	1978	0	0
STATE COMPLEX	NANJING	180000	0	C	1989
STATE COMPLEX	SHANGHAI	60000	0	0	0
STATE COMPLEX	SHANGHAI	85000	1986	0	0
	COUNTRY = CHINA		CHEMICAL = METHANOL		
STATE COMPLEX	LIAOYANG	109000	0	0	0
SICHUAN VINYLON	SICHUAN	300000	0	0	0
STATE COMPLEX	TAI-YUAN,SHANXI	25000	0	0	0
STATE COMPLEX	SHANGHAI	80000	1986	0	0
STATE COMPLEX	QUZHOU,ZHEIJANG	15000	0	0	0
STATE COMPLEX	QUILU	100000	0	0	0
	COUNTRY = CHINA		CHEMICAL = LDPE		
SINOPEC	Daqing	60000	0	0	0
Beijingyan	Fangshan	198000	0	0	0
SHANGHAI GENERAL	Jinshan	60000	0	0	0
LANZHOU CHEMICAL CORP	Lanzhou	24000	0	0	0
Jinlingpch	Nanjing	60000	0	0	0
PANJIN NAT GAS CHEM	Panjin	125000	0	C	1991
CNTIC	Lanzhou	60000	0	P	2000
STATE COMPLEX	BEIJIN-YANSHAN	60000	0	P	2000
	COUNTRY = CHINA		CHEMICAL = LLDPE		
CNTIC	Fushun	80000	0	P	2000
LANZHOU CHEMICAL CORP.	LANZHOU	60000	0	C	1990
	COUNTRY = CHINA		CHEMICAL = HDPE		
State Complex	Liaoyang	35000	0	0	0
n.a.	SHANDONG (QILU)	140000	0	0	0
YANGZI PETROCHEMICAL	YANGZI	140000	0	P	2000
SINOPEC	DAQING	110000	0	0	0
	COUNTRY = CHINA		CHEMICAL = PP		

* ASTIF ASIA CHEMICAL PRODUCTION COMPREHENSIVE LIST *

COMPANY	LOCATION	CAPACITY	YEAR ONSTREAM	STATUS	EXPECTED COMPLETION
Yanshan Petro	Fangshan	35000	0	0	0
STATE COMPLEX	Fangshan	80000	0	0	0
Daqing Petro	Guangzhou	5000	0	0	0
Lanzhou Chemical	Lanzhou	10000	0	0	0
Liaoyang Petro	Liaoyang	35000	0	0	0
Qilu Petrochem	Qilu	15000	0	P	2000
Shanghai Petrochem	Shanghai	70000	0	C	1991
PANJIN NAT GAS CHEM	Panjin	40000	0	C	1991
Yangzi Petrochem	Nanking	140000	0	P	2000

COUNTRY = CHINA CHEMICAL = PS

COMPANY	LOCATION	CAPACITY	YEAR ONSTREAM	STATUS	EXPECTED COMPLETION
State Complex	Fangshan	4000	0	0	0
State Complex	Lanzhou	6000	0	0	0
State Complex	SHANG-GAOQIAO	0	0	0	0
STATE COMPLEX	BEIJING-YANSHAN	60000	0	C	1989
STATE COMPLEX	JILIN	9500	1989	C	1989
STATE COMPLEX	QUILU	25000	0	C	1989

COUNTRY = CHINA CHEMICAL = ABS

COMPANY	LOCATION	CAPACITY	YEAR ONSTREAM	STATUS	EXPECTED COMPLETION
STATE COMPLEX	Lanzhou	10000	1980	0	0

COUNTRY = CHINA CHEMICAL = POLYESTER

COMPANY	LOCATION	CAPACITY	YEAR ONSTREAM	STATUS	EXPECTED COMPLETION
State Complex	Fangshan	37000	0	0	0
State Complex	Jinshan	22000	0	0	0
State Complex	Jinshan	222000	0	0	0
State Complex	Liaoyang	87000	0	0	0
State Complex	Nanjing	120000	0	0	0
State Complex	Tianjin	30000	0	0	0
State Complex	Shanghai	25000	0	0	0
State Complex	BEIJING-YANSHAN	40000	0	0	0
State Complex	Xiaman	30000	0	P	2000
TIANJIN GEN'L FIBRE	Tianjin	80000	0	P	2000
State Complex	Foshan	60000	0	P	2000
JIANGSU-YIZHENG CHEM	JIANSU	183000	0	P	2000
SINOPEC	Jinshan	6600	0	C	1989
TEXTILE IND ZHUHAI	ZHUHAI	30000	0	C	1990
LIAOYANG PETRO	LIAOYANG	32000	0	0	0
STATE COMPLEX	QUILU	70000	0	C	1989

COUNTRY = CHINA CHEMICAL = PVC

* ASTIF ASIA CHEMICAL PRODUCTION COMPREHENSIVE LIST *

COMPANY	LOCATION	CAPACITY	YEAR ONSTREAM	STATUS	EXPECTED COMPLETION
State Complex	Beijing	80000	0	0	0
State Complex	NANJING	200000	0	P	2000
State Complex	SHANDONG	200000	0	P	2000
State Complex	YANGZI	200000	0	P	2000
State Complex	QILU	200000	0	P	2000
ZHU ZHOU CHEM IND	ZHU ZHOU	25000	0	C	1989
STATE COMPLEX	HEFEI	12500	0	P	2000

COUNTRY = CHINA CHEMICAL = SBR

State Complex	Jilin	80000	0	0	0
State Complex	Lanzhou	40000	0	0	0
State Complex	Shanghai	1000	0	0	0
State Complex	Qilu	80000	0	0	0
PANJIN NAT GAS CHEM.	PANJIN	80000	0	C	1991

COUNTRY = TAIWAN CHEMICAL = ETHYLENE

TOTAL CAPACITY		953000	0	0	0
		953000	0	P	2000

COUNTRY = TAIWAN CHEMICAL = PROPYLENE

TOTAL CAPACITY		478000	0	0	0

COUNTRY = TAIWAN CHEMICAL = BUTADIENE

TOTAL CAPACITY		128000	0	0	0

COUNTRY = TAIWAN CHEMICAL = BENZENE

COUNTRY = TAIWAN CHEMICAL = METHANOL

TOTAL CAPACITY		192000	0	0	0

COUNTRY = TAIWAN CHEMICAL = LDPE

TOTAL CAPACITY		240000	0	0	0

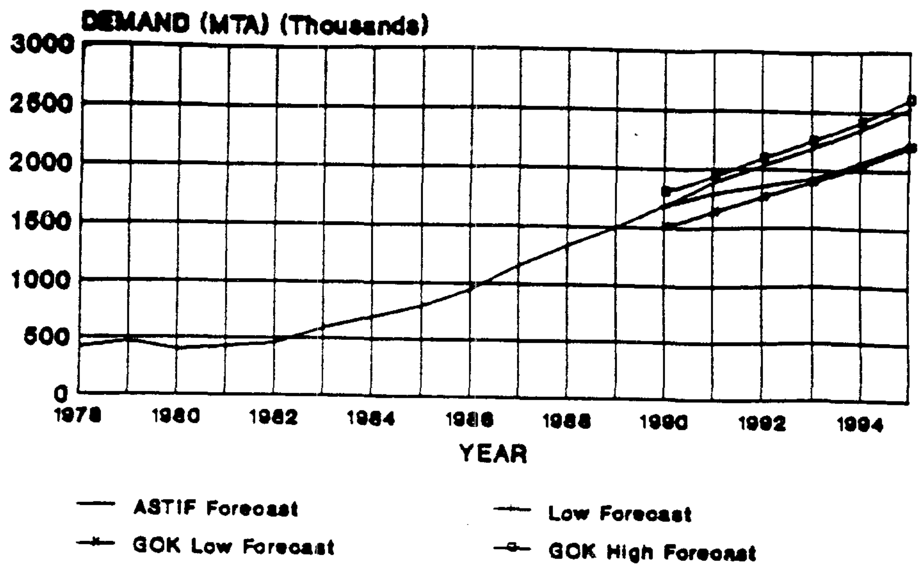
COUNTRY = TAIWAN CHEMICAL = LLDPE

* ASTIF ASIA CHEMICAL PRODUCTION COMPREHENSIVE LIST *

COMPANY	LOCATION	CAPACITY	YEAR ONSTREAM	STATUS	EXPECTED COMPLETION
		120000	0	P	2000
	COUNTRY = TAIWAN	CHEMICAL = HDPE			
		200000	0	0	0
	COUNTRY = TAIWAN	CHEMICAL = PP			
TOTAL CAPACITY		220000	0	0	0
		60000	0	P	2000
	COUNTRY = TAIWAN	CHEMICAL = PS			
TOTAL CAPACITY		223200	0	0	0
	COUNTRY = TAIWAN	CHEMICAL = ABS			
TOTAL CAPACITY		185000	0	0	0
	COUNTRY = TAIWAN	CHEMICAL = POLYESTER			
	COUNTRY = TAIWAN	CHEMICAL = PVC			
TOTAL CAPACITY		220000	0	P	2000
TOTAL CAPACITY		940000	0	0	0
	COUNTRY = TAIWAN	CHEMICAL = SBR			
TOTAL CAPACITY		108000	0	0	0
	COUNTRY = JAPAN	CHEMICAL = ETHYLENE			
TOTAL CAPACITY		4295000	0	0	0
	COUNTRY = JAPAN	CHEMICAL = PROPYLENE			
TOTAL CAPACITY		2510000	0	0	0
	COUNTRY = JAPAN	CHEMICAL = BUTADIENE			

DEMAND PROJECTIONS FOR PETROCHEMICALS

Figure 6.2 KOREA HISTORICAL AND FORECAST DEMAND
CHEMICAL: ETHYLENE



Source: Staff Estimates

Figure 6.3 KOREA HISTORICAL AND FORECAST DEMAND
CHEMICAL: BENZENE

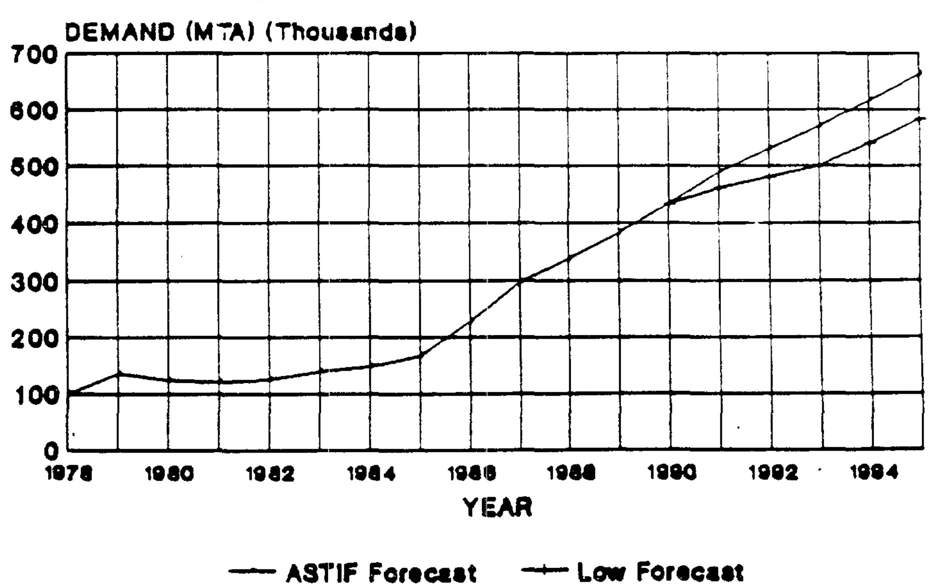
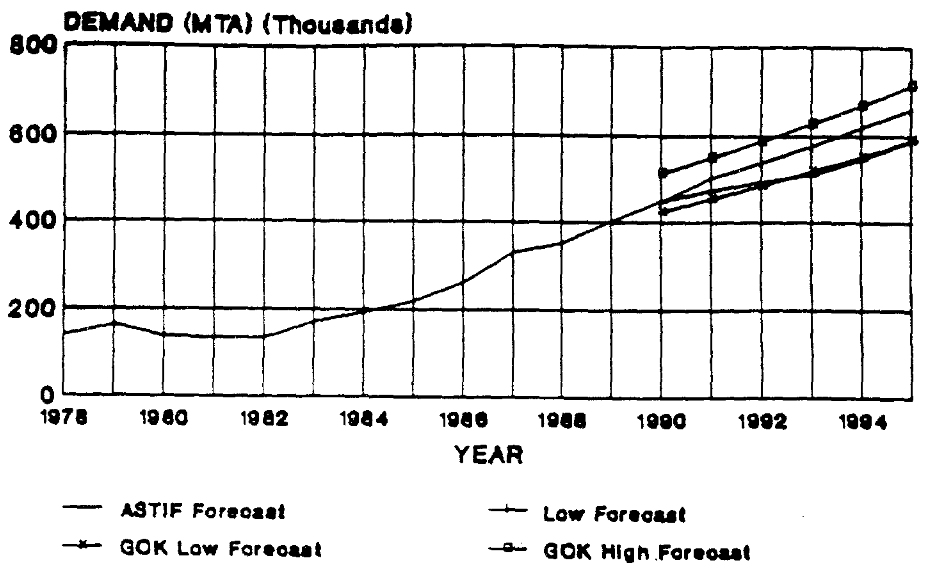


Figure 6.4

KOREA HISTORICAL AND FORECAST DEMAND CHEMICAL: LDPE



Source: Staff Estimates

Figure 6.5

KOREA HISTORICAL AND FORECAST DEMAND CHEMICAL: HDPE

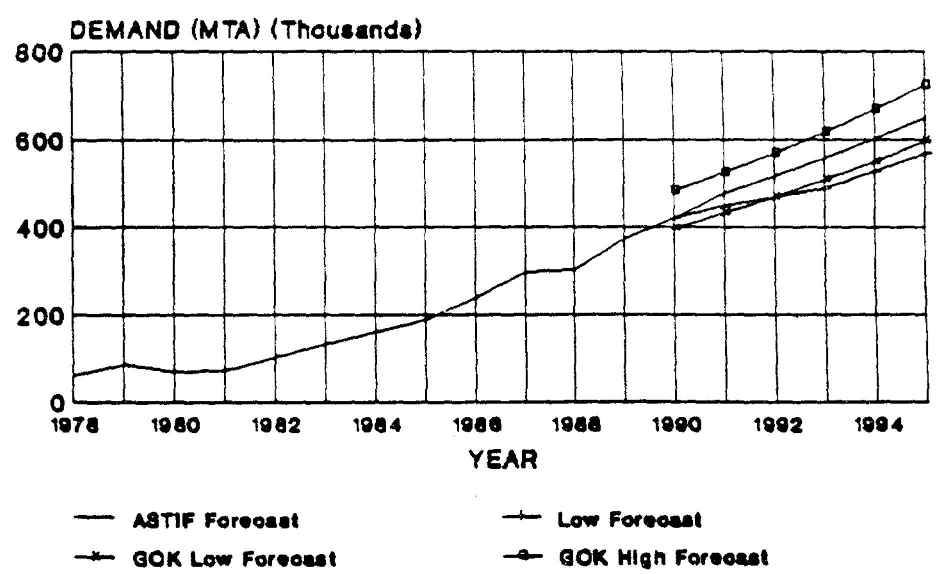
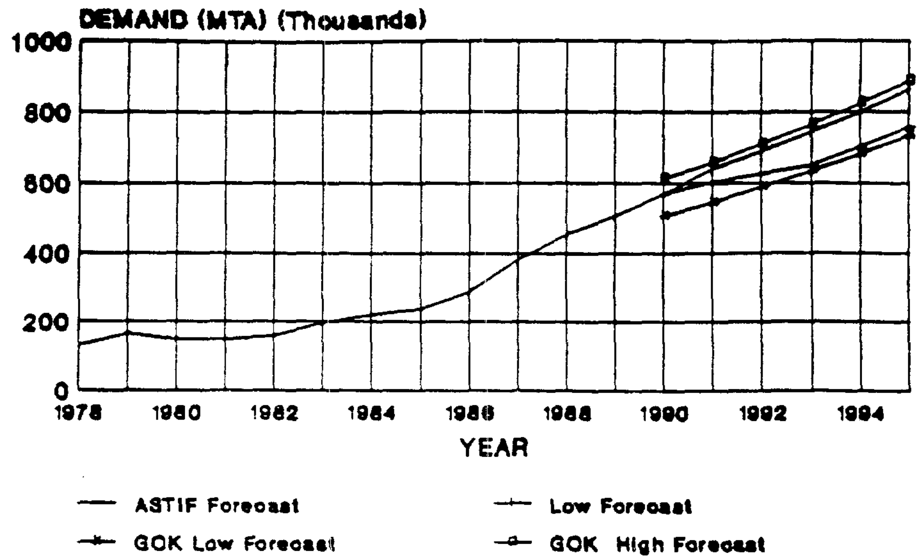


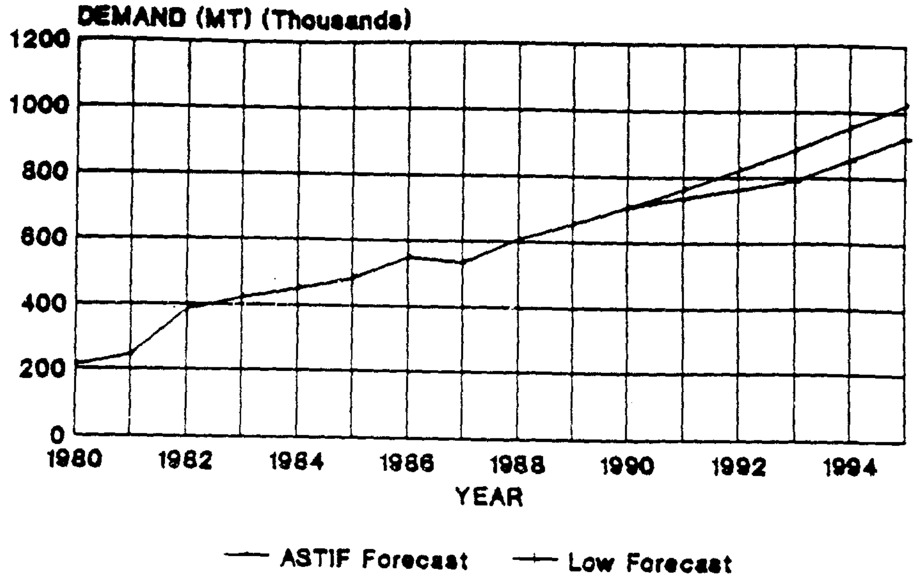
Figure 6.6 **KOREA HISTORICAL AND FORECAST DEMAND CHEMICAL: PP**



Source: Staff Estimates

Figure 6.7

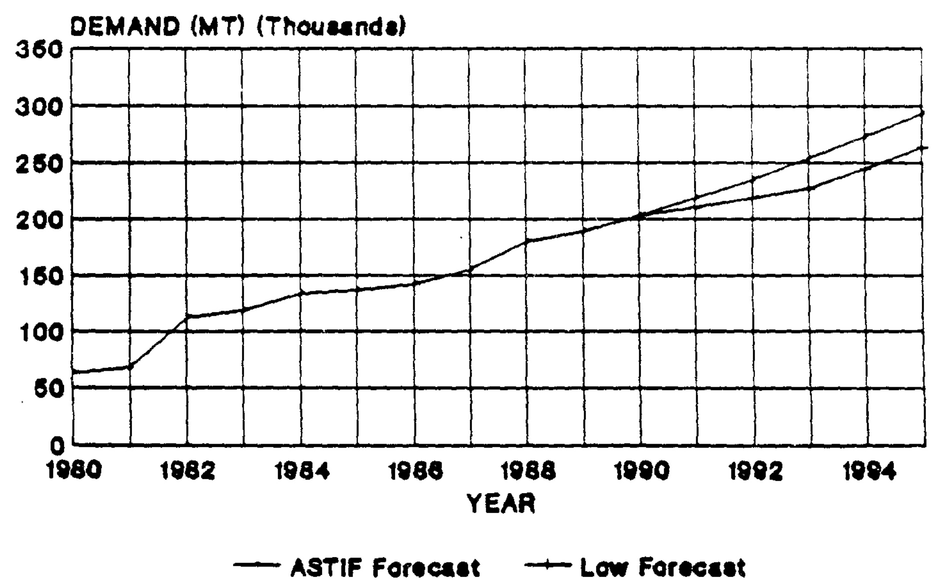
INDIA DEMAND FORECAST
CHEMICAL: ETHYLENE



Source: Staff Estimates

Figure 6.8

INDIA DEMAND FORECAST
CHEMICAL: PROPYLENE



Source: Staff Estimates

Figure 6.9 **INDIA DEMAND FORECAST CHEMICAL: LDPE/LLDPE**

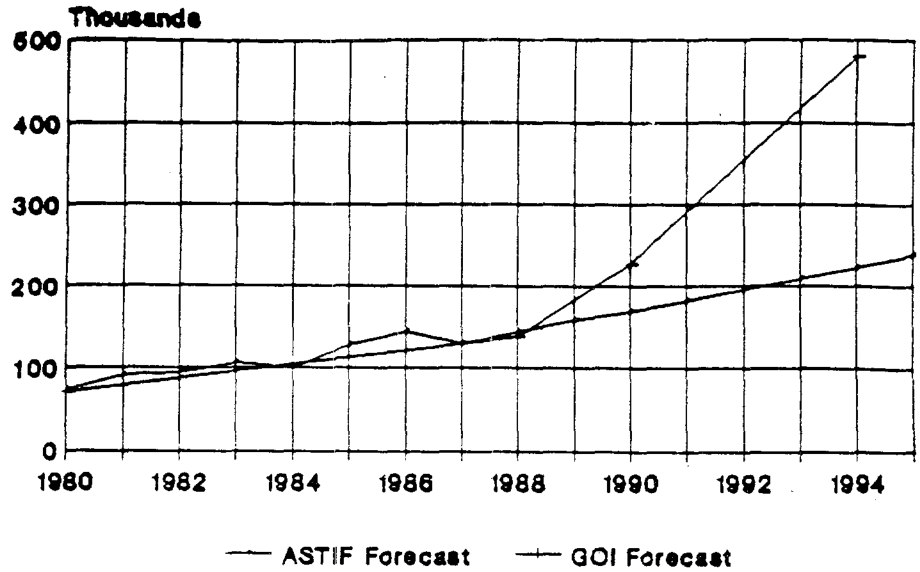
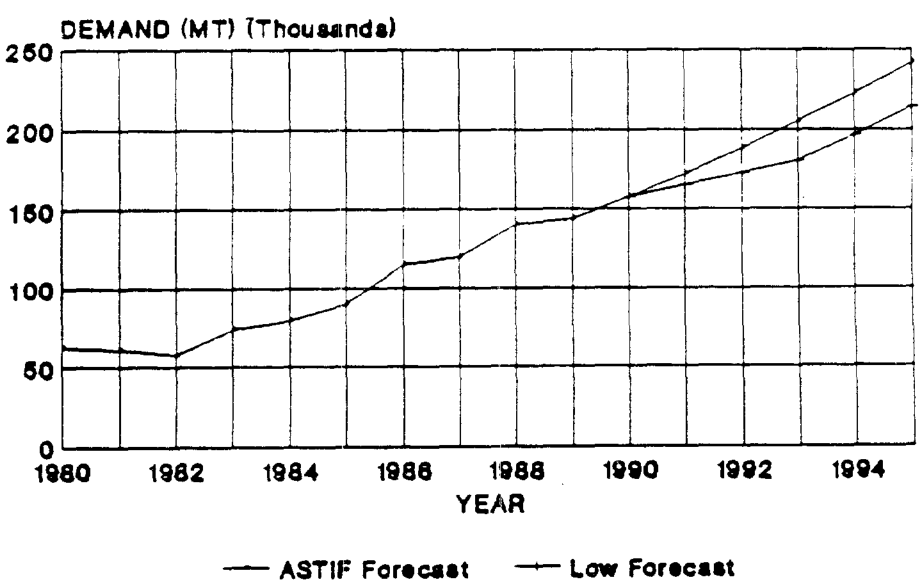
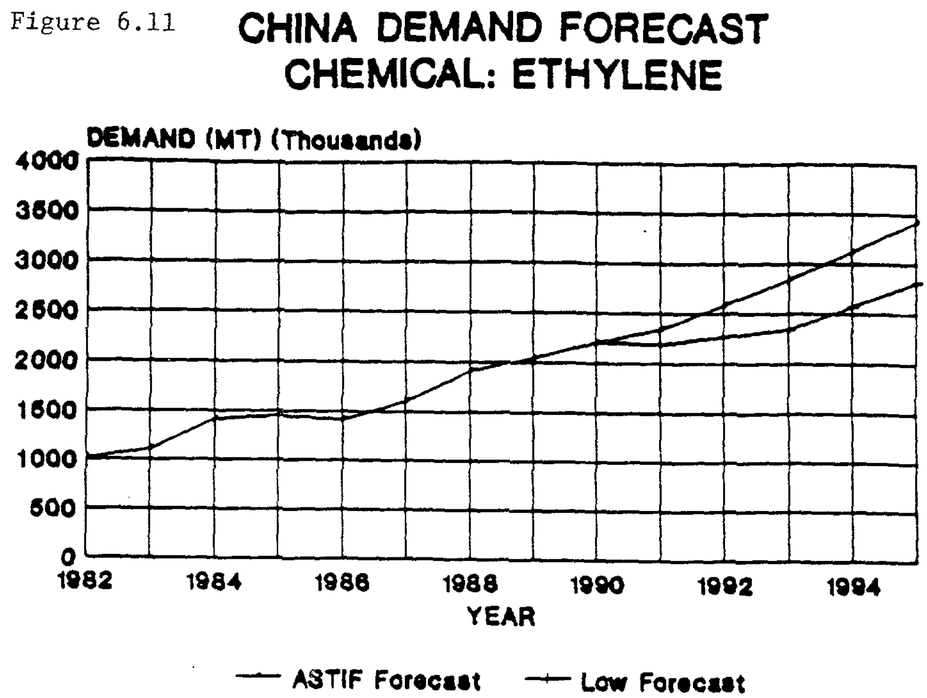


Figure 6.10 **INDIA DEMAND FORECAST CHEMICAL: HDPE**



Source: Staff Estimates

Figure 6.11



Source: Staff Estimates

Figure 6.12

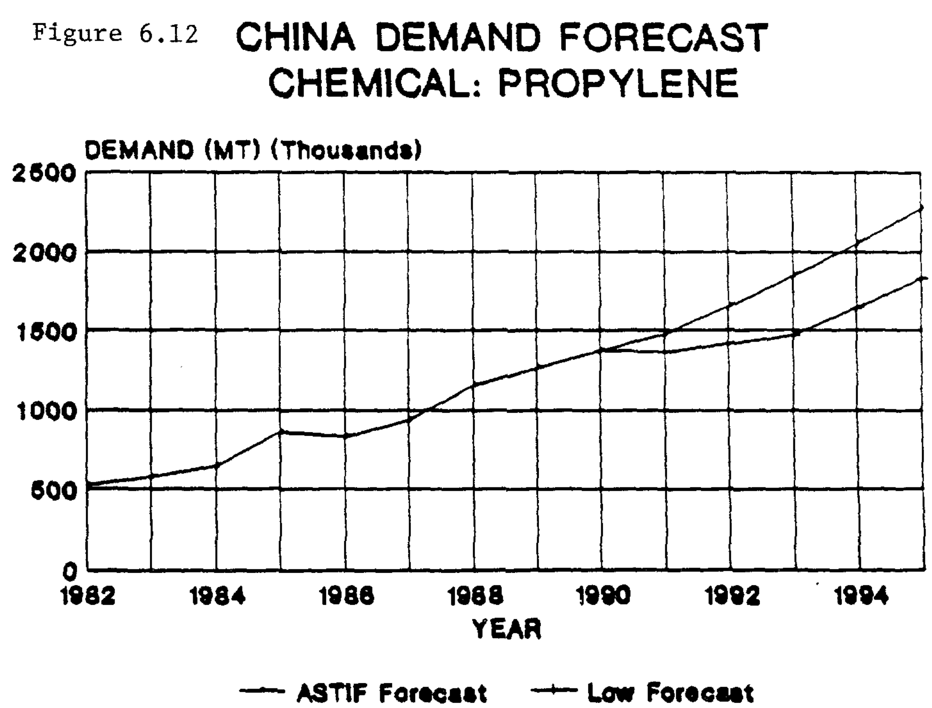
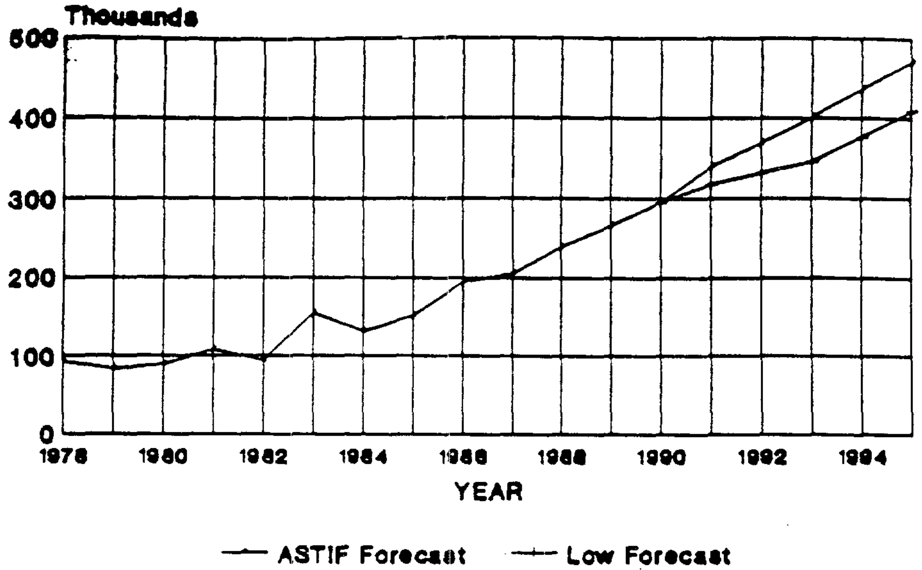


Figure 6.13

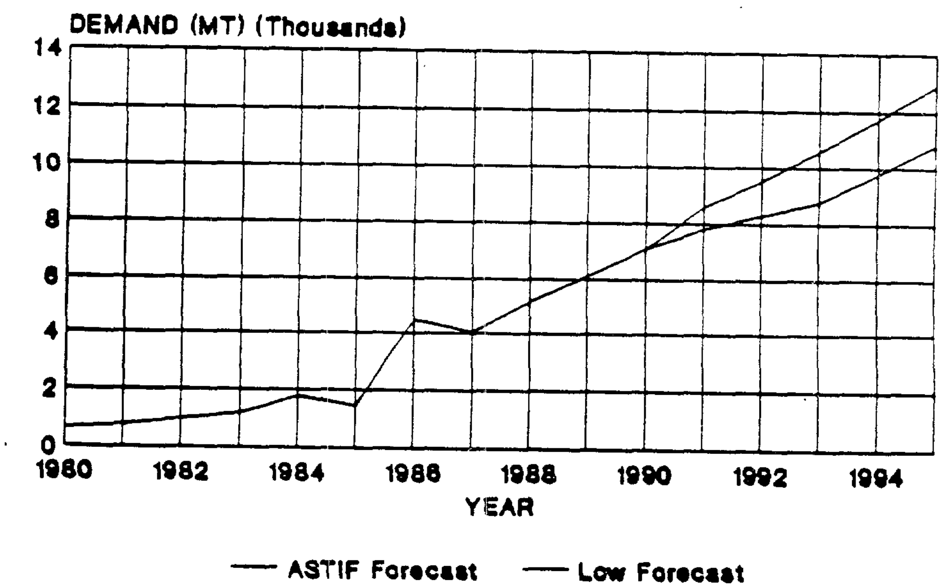
THAILAND DEMAND FORECAST
CHEMICAL: ETHYLENE



Source: Staff Estimates

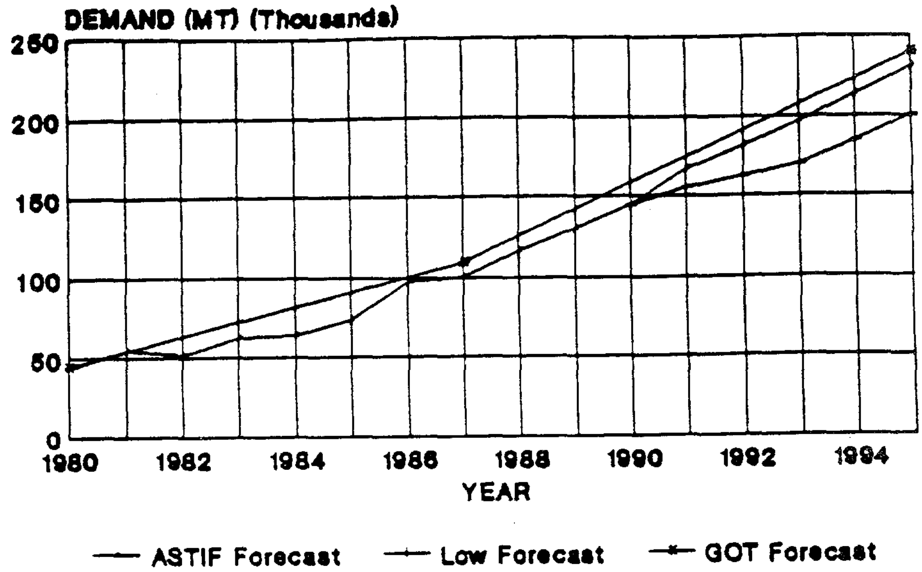
Figure 6.14

THAILAND DEMAND FORECAST
CHEMICAL: BENZENE



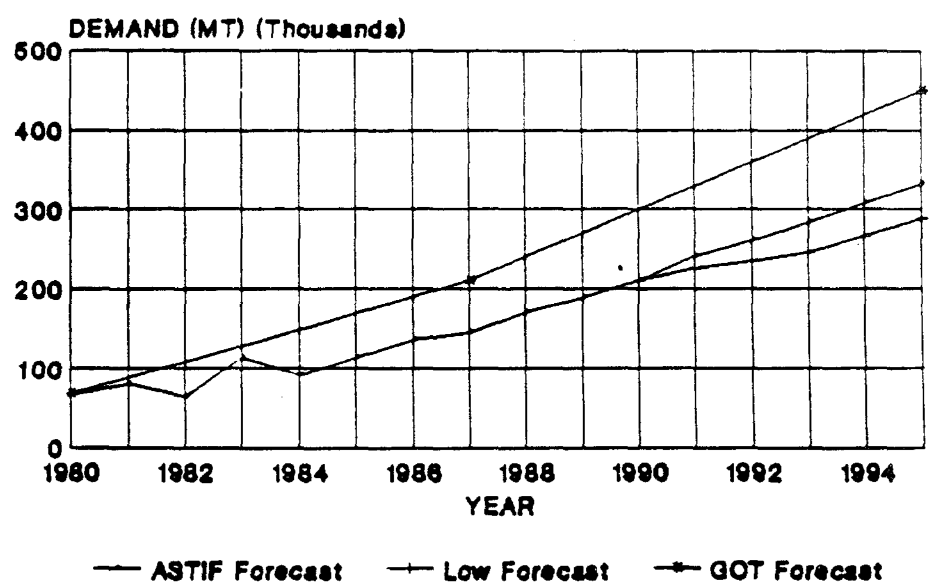
Source: Staff Estimates

Figure 6.15 THAILAND DEMAND FORECAST CHEMICAL: POLYPROPYLENE



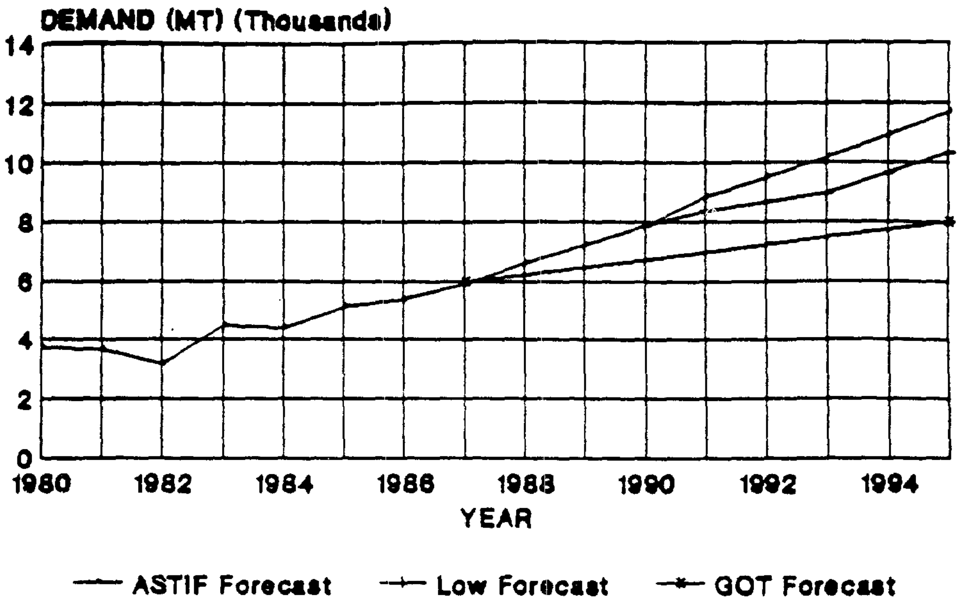
Source: Staff Estimates

Figure 6.16 THAILAND DEMAND FORECAST CHEMICAL: TOTAL POLYETHYLENE



Source: Staff Estimates

Figure 6.17 **THAILAND DEMAND FORECAST CHEMICAL: SBR**



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