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Brazil: Nearing Oil Self-Sufficiency



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A Research Paper

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*GI 86-10024
April 1986*

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Brazil: Nearing Oil Self-Sufficiency

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A Research Paper

This paper was prepared by [Redacted] and [Redacted] of the Office of Global Issues, and [Redacted] Office of African and Latin America Analysis, with contributions from [Redacted] OGI, and [Redacted] the Analytical Support Group. [Redacted]

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Comments and queries are welcome and may be directed to the Chief, Strategic Resources Division, OGI, [Redacted]

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**Brazil:
Nearing Oil Self-Sufficiency**



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Key Judgments

*Information available
as of 7 March 1986
was used in this report.*

With adequate investment, Brazil is in a position to reduce substantially, if not eliminate, its dependence on imported oil. Recent discoveries of about 1.3 billion barrels in the offshore Campos Basin would technically allow Brazil to boost domestic oil production to more than 900,000 barrels per day (b/d) by the early 1990s—an increase of over 60 percent, compared with 1985 levels. Because of the high probability of additional offshore oil finds, we believe that Brazilian production could increase to the 1.0-million-b/d range by the late 1990s and that the reserve base should be sufficient to support that level of output for at least a decade.



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Given the high priority placed on energy independence and the large investment Brazil has already made in the petroleum equipment and services industry, we feel that Brasilia will make the new investments needed to exploit the new Campos finds. If world oil prices continue to fall, a point may be reached where political pressures and economic factors could force Brazilian planners to stretch out the development time of the new offshore oilfields. Doing so, however, would prolong Brazil's dependence on imported oil, and self-sufficiency would probably be out of reach until the turn of the century. All things considered, we believe Brazil will proceed with a fairly rapid development of the fields.



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The substantial progress we project Brazil will make in limiting imports reflects sizable production increases and modest growth in domestic oil demand. We see little likelihood of major backsliding in domestic oil conservation efforts. Vigorous conservation measures in place since the mid-1970s, coupled with hefty gains in domestic oil production, have already helped Brazil cut its annual import bill from about \$9.9 billion in 1981 to approximately \$4.3 billion in 1985—an amount that is equal to 35 percent of Brazil's annual interest payments on its foreign debt.



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To the extent that Brazil remains saddled with its huge foreign debt, keeping the import bill as low as possible will remain a priority objective. Development of the new offshore fields will be an important part of any program to improve Brazil's international trade and payments picture and will help protect the financial stake that US and other foreign banks have in Brazil's future. At a world oil price of \$20 per barrel, production from the new Campos fields would result in cumulative savings of at least \$7 billion in foreign exchange from 1989 through to the early 1990s. Lower oil


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import expenditures will most likely ease Brazil's debt burden by facilitating payment of interest and lowering requirements for new money. Despite these benefits, we believe it unlikely that Brasilia will significantly alter its position on debt negotiations with international creditors. 

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Development of the new oil finds will also provide important opportunities for the United States. Brazil might be willing to make trade concessions given the further leeway lower oil expenditures would produce in the trade account. The US oil service industry will benefit from engineering and drilling opportunities provided by the deepwater finds. Development of the new Campos fields will not lead to significant diversions of technology to US competitors or the Soviet Bloc. 

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Brazilian firms, however, are among the world leaders in offshore development and will benefit greatly from the impetus provided by the new Campos discoveries. In fact, technology already transferred to Brazil through licensing and other arrangements with foreign companies could put Brazilian firms in a much stronger position to compete in the worldwide offshore market in the next decade. 

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**Brazil:
Nearing Oil Self-Sufficiency**

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Brazil's New Oil Discoveries

Brazil has discovered large new offshore oil deposits that have the potential by the early 1990s to reduce, if not eliminate, the country's dependence on imported oil. Although down sharply from the 1981 peak, Brazil's net oil import bill amounted to \$4.3 billion in 1985, equivalent to about 35 percent of the interest Brazil pays annually on its huge foreign debt.

The Brazilian State Oil Company—Petrobras—is currently exploring a new oil-bearing region in the offshore Campos Basin. Results, thus far, have been exceptionally good. According to trade journals, exploration drilling to date has resulted in the discovery of two large fields containing over 1.3 billion barrels of recoverable oil. To put this figure into perspective, these discoveries alone represent:

- A nominal six-year supply at Brazil's current rate of production.
- A 65-percent increase in Brazil's proved oil reserves, which stood about 2.0 billion barrels prior to the new discoveries.

The smaller field (1-RJS-305) contains an estimated 300 million barrels of oil and is located in waters shallow enough (300 to 400 meters) to permit commercial development using existing offshore production technology. The giant field (1-RJS-219) contains at least 1 billion barrels but is at a water depth of 900 meters, and new techniques will be needed to exploit this area.¹

Both fields have excellent reservoir characteristics and can produce oil at high rates. From a technical perspective, this means that the production capacity of the reservoirs is favorable because the porosity and permeability of the source rocks are good. On the basis of production tests, the production per well in the new fields will be in the 5,000- to 15,000-barrels-per-day (b/d) range. This high production rate will

¹ A giant field contains at least 1 billion barrels of oil.

Geology of Oil Deposits

The three factors necessary for the accumulation of oil are source beds, traps, and seals. Source beds are usually organically black, marine shales that will generate oil when subjected to sufficiently high temperatures caused from being buried at great depths for a long time. As the oil is generated, it is ejected from the source beds and travels into traps or reservoirs that are formed by a number of geological mechanisms, such as folding and faulting. Reservoir rocks with good production capacities have a large number of interconnected cavities that allow rapid oil flow. Reservoir seals are impervious barriers of sediments that cover the reservoirs thus preventing further oil migration either upward or laterally.

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The Campos Basin is geologically analogous to offshore oil-producing regions in Angola. During the Cretaceous period some 120 million years ago and prior to the separation of the continents, the present Campos Basin and offshore Angolan fields were geographically contiguous areas. Because the analogous Angolan fields have been well explored and productive for some time, we have good confidence in our assessments of the geological characteristics of the new Campos fields.

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allow the fields to be produced with a small number of wells, an important consideration in light of the depth of the new fields. According to Brazilian press reporting, both fields will be in commercial production by the early 1990s. Although it is technically possible that the fields could be developed in this time frame, uncertain world oil prices could tempt Brazilian planners to take a slower approach.

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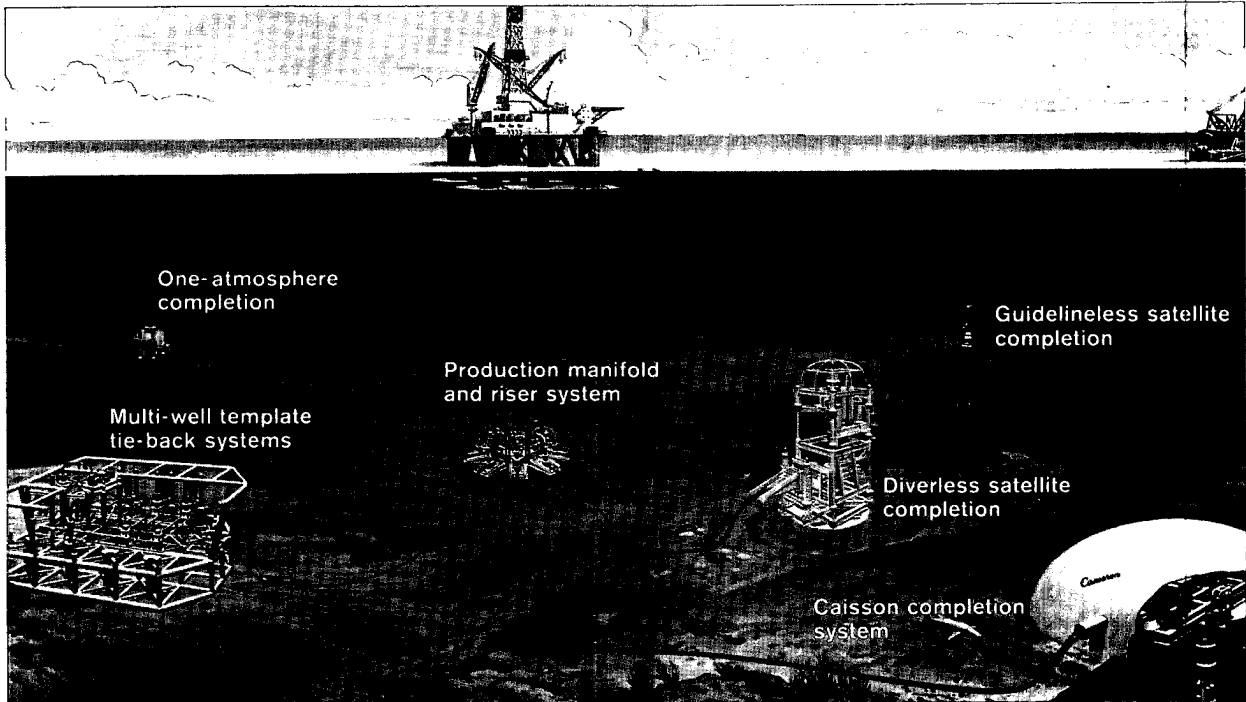
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Early Production Systems

An Early Production System (EPS) is aimed at bringing a new oil discovery on stream in the fastest possible time—for example, 12 months or less from completion of the discovery well. Petrobras is a world leader in EPS technology and has used this technique for many years to exploit other fields in the Campos Basin. The system consists of wellheads on the ocean floor and processing facilities—oil and gas separators, flares, and other oil production equipment—usually on a jack-up or semisubmersible drilling rig.

The oil flows to the surface by natural pressure, is processed on the rig, passed onto a storage tanker moored nearby to a system of buoys, and taken ashore by shuttle tanker when it is full. Early Production Systems are economically attractive because they eliminate the higher initial cost of building and installing more permanent and involved production structures, and because they deliver a quick inflow of oil revenue.

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Equipment used in subsea production

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According to our analysis, the new Campos discoveries give Brazil the potential to approach oil self-sufficiency in the latter half of the 1990s. We believe there is a good possibility that, despite likely decline trends in existing fields, Brazil will expand oil output from 560,000 b/d in 1985 to the 1-million-b/d range by the mid-to-late 1990s if, as we expect, additional oil is found and developed in other areas of the Campos Basin and in potentially promising areas of the Sergipe-Alagoas Basin to the north (see appendix).

Production Obstacles To Be Overcome

Investment Requirements

the cost of developing the new Campos fields will be roughly \$20 billion; this suggests an average development cost of up to \$15 per barrel. By any yardstick, such average

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development costs are high. For example, in other offshore oil-producing regions such as the Bay of Campeche and the North Sea, average development costs are in the \$5- to \$12-per-barrel range. The extreme depth of the larger field in the Campos Basin is the major factor pushing development costs up. Our calculations suggest that, when operating and transportation costs are added, total costs in the Campos Basin could be as high as \$20 per barrel (in terms of current prices)—establishing this region as perhaps the world's highest cost oil producer. [redacted]

There are several factors, however, that make such expensive oil attractive despite the high cost per barrel. Since most of the oil would be produced in the 1990s, it is possible that prevailing oil prices then would justify development costs. The majority of the development costs would involve domestic resources—specialized labor and indigenous technology and materials—rather than hard currency outlays for imported labor and material. These resources were developed by Brasilia specifically for petroleum exploration and development and, at least in the short run, would have little value if directed toward other industrial projects. The hard currency costs of the Campos oil would be only a small portion of the total. [redacted]

Petrobras appears to be gearing up for the large investment program needed to expand production and continue an aggressive exploration program in the Campos Basin. According to press reporting, a state company spending plan released in January allocates \$2.8 billion to Petrobras for investment in 1986—a 40-percent real increase compared with last year. In early February, however, the administration disclosed that President Sarney has decided to reduce funding for oil exploration. The extent of the cut has yet to be determined, but, in light of the importance energy independence has on Brazil's national security, we believe that the reduction will be moderate. Even a less-than-hoped-for increase in investment would still represent a dramatic turnaround in the government's investment in the oil sector that has declined steadily since 1983. [redacted]

Technology Requirements

[redacted] it is technically possible to develop the deepwater offshore finds without major difficulty. The Brazilians are already routinely operating at depths of more than 300 meters, and in 1985

Petrobras established a world record by producing oil at 385 meters. Petrobras' past experience and technical expertise should allow it to develop its current discoveries as deep as 700 meters without difficulty. Production at a 900-meter depth, however, will require adaptation of existing technology and probably assistance from US, Canadian, and West European engineering and construction companies. Brazil is already working with foreign companies to develop deepwater production equipment to develop its deep finds. [redacted] Petrobras recently began discussions with a US firm on development of deep sea oil production technology. [redacted] [redacted] Brazil wants the deep field in the Campos Basin operating by 1990. [redacted]

Uncertain Oil Market Conditions

[redacted] our own view, is that world oil prices will continue to experience downward pressure in the future. A slack oil market represents a mixed blessing for Brazil. A drop in world oil prices over the short-to-medium term would free additional funds, part of which could be invested in the oil sector. According to our analysis, at world oil prices of \$20 per barrel, Brazil's annual hard currency savings would amount to about \$1.7 billion. At \$15 per barrel, annual savings would increase to about \$3.0 billion. In either case, Brazil would have the opportunity to earmark some of the savings for offshore oil development to ensure continued progress in its drive for energy independence. [redacted]

On the other hand, if prices average well below Brazil's cost of production for an extended period of time, Petrobras will probably be forced to scale back its pace of oil exploration and development. [redacted]

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Brazil: Oil Production, Imports, and Consumption, 1970-85*Thousand barrels per day*

	Production	Imports	Consumption
1970	167	345	512
1975	177	701	878
1980	187	906	1,093
1981	220	809	1,029
1982	268	750	1,018
1983	339	622	961
1984	472	478	950
1985 ^a	560	400	960

^a Preliminary.
Curbing Domestic Consumption

In addition to hefty increases expected on the supply side, we believe that the Brazilian Government will continue policies aimed at curbing oil consumption. During the 1970s, Brazil's domestic oil consumption grew at an average annual rate of 9 percent, among the fastest rates of growth registered in the LDCs. Rapidly increasing consumption, stagnant domestic production, and a sharp rise in world oil prices combined to push Brazil's net oil import bill up from about \$325 million in 1970 to \$9.9 billion in 1981—almost a thirtyfold increase.

Faced with these costs, in the late 1970s the Brazilian Government launched a program to curb oil consumption by encouraging oil substitution, developing nonoil energy sources, and raising petroleum prices across the board. The National Alcohol Program, in particular, has contributed substantially to reducing gasoline demand. These policies, along with domestic economic recession, resulted in a drop in both consumption and imports. Oil consumption in 1985 amounted to 960,000 b/d, down 12 percent compared with 1980. The drop in imports has been even more dramatic, falling from about 1 million b/d in 1979 to about 400,000 b/d in 1985—the lowest level since the early 1970s (see table). This decline, coupled with lower

world oil prices, caused Brazil's net oil import bill to fall to \$4.3 billion in 1985. While the reduction in the oil import bill represents a significant improvement in Brazil's financial picture, annual outlays of \$4.3 billion still represent about 35 percent of Brazil's annual interest payments on its foreign debt, clearly indicating that it is in Brazil's interest to continue efforts to curb imports.

Outlook for Self-Sufficiency**Demand Outlook**

We believe that continued annual economic growth of 4 percent or more and weakness in world oil prices will generate some growth in Brazilian domestic oil consumption. Government programs developing alternative energy fuels, however, will temper oil growth and will keep it well below the rates posted in the 1970s. We estimate that hydroelectricity, natural gas, and coal will continue to expand their market shares, with most of the growth occurring in the power and residential sectors.

, we estimate that Brazilian oil demand will increase to a range of 1.0-1.2 million b/d by the early 1990s, implying an average annual increase of at most 3 percent. It is possible, although unlikely, that a sharp and lasting fall in world oil prices with the resultant increase in economic activity could boost consumption to perhaps as high as 1.5 million b/d by the early 1990s.

Most of the growth in consumption will occur in the industrial and transportation sectors. Although fuel oil use in the industrial sector has dropped considerably—due primarily to economic recession—energy efficiency has not improved significantly, and the conversion of oil-fired generators to coal has been limited in scope. Demand for diesel fuel will probably rise because of development of rural areas and rising industrial activity, resulting in increased demand for public transportation and freight transport. Although alcohol fuel will continue to substitute for gasoline, the rate of substitution is likely to slow and gasoline consumption should increase to support an expanding motor vehicle fleet.

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The National Alcohol Program

The National Alcohol Program (PROALCOOL) has been an important factor in Brazil's oil substitution efforts. The first five years of the program were devoted to constructing distilleries as annexes to existing sugar mills, with the goal of producing alcohol as a gasoline additive. Since 1980, emphasis has been placed on developing car engines to run on pure alcohol. As a result, 90 percent of new cars are alcohol powered, and special orders must be placed for gasoline-powered cars.

Although government support for PROALCOOL has been reduced since 1980, subsidies continue to represent a significant financial burden for Brasilia. According to press reporting, subsidies over the past four years have amounted to a total of \$5 billion, or 40 percent of annual interest payments to Brazil's creditors. It is uncertain what effect the elimination of government subsidies would have on the program. Some analysts believe that the alcohol industry is saddled with inefficient producers who, without government aid, would have folded long ago. Others believe that subsidies are no longer needed because the existing facilities are able to generate their own resources for reinvestment in new projects. We believe, however, that, if subsidies are removed, Brasilia will have to compensate alcohol producers by raising alcohol and gasoline prices—which is politically unpalatable for Sarney in light of triple-digit inflation.

As a short-term solution to this problem, President Sarney has banned construction of new alcohol plants until 1989 and has imposed a freeze on the current percentage of alcohol-powered cars that the automobile industry is allowed to produce. In doing this, President Sarney probably hopes to send a signal to the alcohol industry that the government will no longer subsidize inefficient production. Moreover, efforts are currently under way to move the alcohol program in the direction of technological improvement toward obtaining greater productivity from crop harvesting and production processes.

Although there have been few complaints about conservation programs registered to date, objections to the government-subsidized alcohol program are surfacing as the oil market continues to weaken. As a result, Brasilia is considering capping alcohol production. Given the structural adjustments and substantial capital investment made by both government and industry in the last five years, we believe that there would have to be a sharp and sustained drop in prices before any major backsliding on oil conservation or the official intention to hold oil consumption in check.

Supply Outlook

Development of the two new fields in the Campos Basin should allow Brazil to narrow, if not eliminate, its present dependency on imported oil by the early 1990s. Much will depend on the speed at which the new fields are developed and the investments that are forthcoming. We believe that most factors point toward fairly rapid development:

- Production from existing fields will probably drop from its present level of 560,000 b/d to as low as 360,000 b/d by the early 1990s. Unless offset by increased output from the new Campos Basin discoveries, Brazil's import requirements could rise to almost 750,000 b/d by the early 1990s, compared with about 400,000 b/d in 1985. Assuming world oil prices of \$20 per barrel, this would represent a \$2.5 billion increase in Brazil's import bill during that time frame.
- Oil self-sufficiency for Brazil is a national security imperative to reduce dependence on foreign supplies and the impact of external factors on the economy.
- Offshore oil activity has spurred development and enlargement of the oil services industry in Brazil, creating thousands of jobs that would be lost if Brazil curtailed its offshore efforts.

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- Development of offshore oil, particularly in deep water, requires a long lead time, and full production from the new fields will not occur until the next decade, when many industry experts believe oil prices will be strong. Indeed, a world oil price of \$20 per barrel could well prove to be a conservative estimate of the price likely to prevail in world markets during the 1990s.
- The majority of the \$20 billion needed to develop the new fields will not be required until approximately 1990. Between now and then, a relatively small hard currency investment (possibly in the \$50-100 million range) will be needed mainly for assistance in designing the deepwater rigs.
- The cost of developing the new discoveries will be insulated from world oil prices because more than 90 percent of the services and equipment needed to develop the fields will be supplied domestically and paid for in Brazilian currency.

Development of the two new fields in the Campos Basin would allow Brazil to increase output to more than 900,000 b/d by the early 1990s, compared with 560,000 b/d in 1985. On the basis of typical development trends in new fields, we would expect to see production increasing gradually to perhaps 650,000 b/d by 1990 and then rising sharply in the next two to three years. In such an event, Brazil would come close to covering its oil needs by the early 1990s, at least at the low end of our demand estimate (see figure 2). Barring additional oil discoveries, however, this period of near self-sufficiency could be short-lived. Without additional discoveries and with the inevitable declines that will occur as fields age, Brazilian output could well be starting to decline by the mid-1990s.

On the basis of our analysis of Brazil's offshore geology, we believe the odds are good that Brazil will make the oil discoveries necessary to maintain its reserve base and increase production to 1 million b/d by the year 2000. Drilling is planned on six additional structures in the Campos Basin, which Petrobras believes could each contain about 1 billion barrels. Exploration in the geological trend connecting the Campos and Sergipe-Alagoas Basins is also likely to discover more oil. Exploration, to date, has concentrated on basins at either end of the trend, but the

sedimentary basins in the center of this region may also contain oil. Given the paucity of reliable information on this area, it is impossible to place an exact number on the amount of oil that may be found. But, on the basis of analogous oil-bearing trends, it is possible that up to 4 billion barrels could be discovered by the end of the century. How much additional oil is ultimately found depends, of course, not only on favorable geological conditions, but also on whether the needed investment is forthcoming.

Given the current rate of exploration drilling, Brazil is likely to discover sufficient reserves to support production of an additional 580,000 b/d by the mid-to-late 1990s. Providing these deposits are exploited rapidly and allowing for declines as other areas age, we expect that Brazil should be able to sustain production in the 1.0- to 1.2-million-b/d range into the next century without straining its reserve base.

Implications for Brazil and the United States

For Brazil

Increased domestic oil production and lower oil imports will have important direct and indirect benefits for the Brazilian economy. During the short-to-medium term, the oil industry is likely to be an important source of employment in the services, construction, and transport sectors. The \$7 billion invested in the Campos Basin since the early 1970s has created approximately 25,000 new jobs. Domestic firms currently produce 90 percent of the equipment and services used in the oil sector, and almost all future drilling and development work in the Campos Basin will be handled by Brazilian firms. Domestic firms already have been awarded \$400 million for the construction of four fixed steel production platforms.

Lower oil imports will provide some relief from the debt service pressures facing Brasilia, although we believe Brazil will still require some rescheduling or new borrowing. At a world market price of \$20 per

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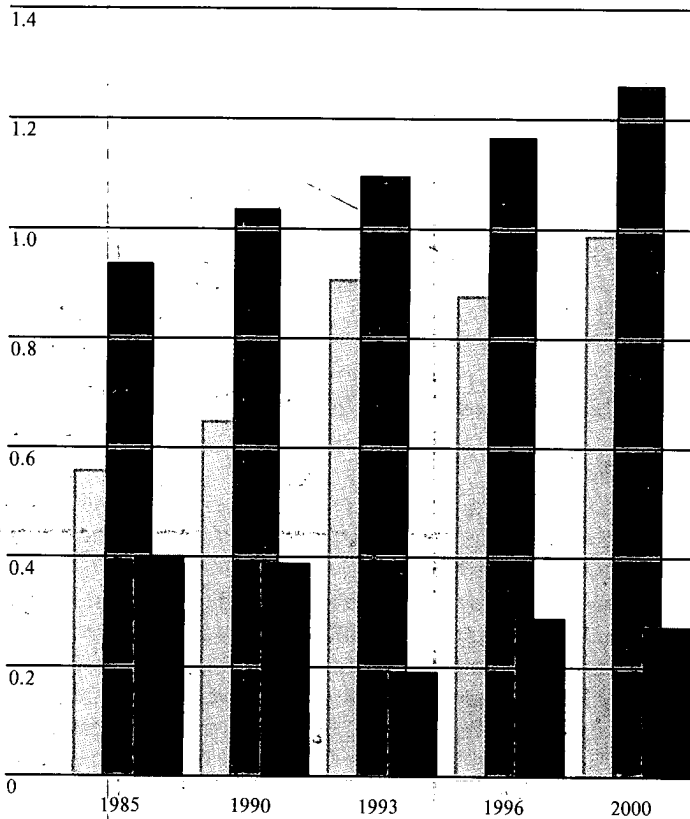
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Figure 2
Brazil's Oil Picture: Likely Scenario

Oil balance

Million barrels per day

Production Consumption^a Imports

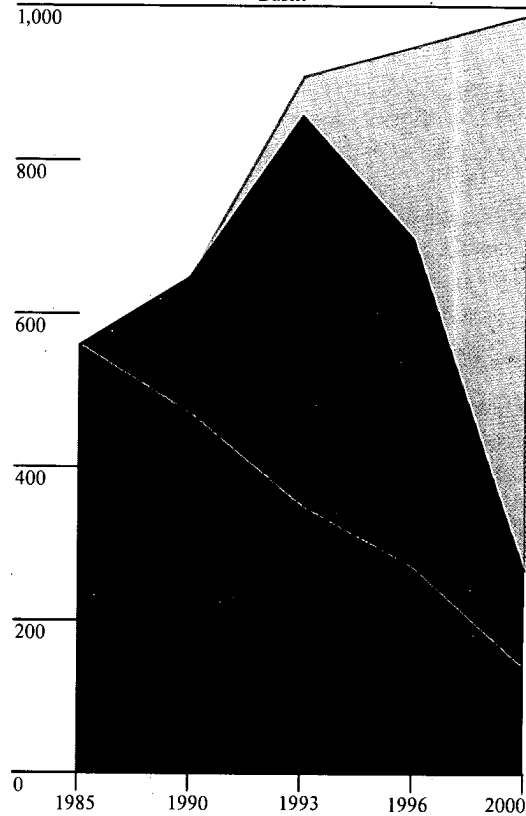


^a Assuming mid-range of consumption forecast

Sources of oil production

Thousand barrels per day

Future discoveries New Campos Basin Existing fields



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barrel, production from the new Campos fields would result in cumulative savings of at least \$7 billion in foreign exchange from initial production through the early 1990s. While some of these savings most likely will be applied to debt servicing, or postponement of new money requests, competing demands probably will force Brazil to spread the benefits of lower oil imports to other sectors of the economy. As a result, we deem it unlikely that Brasilia will alter its position on debt negotiations and will insist on rescheduling of principal. An improved trade balance, however, would bolster Brazil's creditworthiness and may reduce the reluctance of US and other foreign banks to provide new loans to Brazil. The improved international payments situation, in turn, would allow Brasilia some flexibility in domestic policies, perhaps permitting a more growth-oriented approach. [redacted]

The stimulus of Campos development will also improve the export competitiveness of Brazil's petroleum equipment and services industry. Last year, Petrobras, through its subsidiaries, sold abroad more than \$1 billion in offshore oil services and equipment. Greater exports are likely as Brazil gains worldwide leadership in offshore oil production, particularly deepwater drilling and early production systems. Petrobras recently signed a joint venture agreement with a British engineering firm to market its offshore oil development expertise in Early Production Systems to the world market. Further deals such as this could result in substantial foreign exchange earnings. [redacted]

For the United States

Full development of the Campos Basin also presents some important trade opportunities for the United States:

- Exploitation of deepwater finds will require significant foreign engineering assistance from US, Japan, and West European companies. Petrobras has already begun working with several US firms.
- Additional offshore exploration will provide opportunities for US companies to win drilling contracts.

[redacted]

- Brazil will probably be more willing to make trade concessions given the further leeway that lower oil expenditures will produce in the trade account. An easing of restrictions for nonoil imports would increase chances for US exports to enter Brazil. [redacted]

While the Campos effort may create new trade opportunities for hard-pressed US petroleum services and equipment firms, these firms will face stiff challenges. In the past, Petrobras has preferred US technology. Now, however, with the huge investment requirement ahead, a major consideration in the choice of technology will be cost. Petrobras is examining Japanese and West European technology, which may be less costly for the new Campos fields. US firms can also expect competition for drilling contracts. [redacted]

Technology transfer through development of the new Campos fields will probably not lead to significant diversions either to US competitors or to the Soviet Bloc. The potential worldwide demand for specialized deepwater production equipment is not large enough to justify development of a wholly independent Brazilian manufacturing base for this type of equipment. Nor will the technical demands of this development be enough to spur Brazil's efforts in sophisticated computer-based robotic technology, which is most prized by the Soviet Union. Nevertheless, US firms will face additional Brazilian competition in the world oil services market and in low-technology sectors of the deepwater oil equipment market where Brazil already has the manufacturing capacity. The Brazilian offshore industry will gain unique deepwater experience during development of the Campos Basin that will enhance its current position as one of the leaders in offshore oil development. [redacted]

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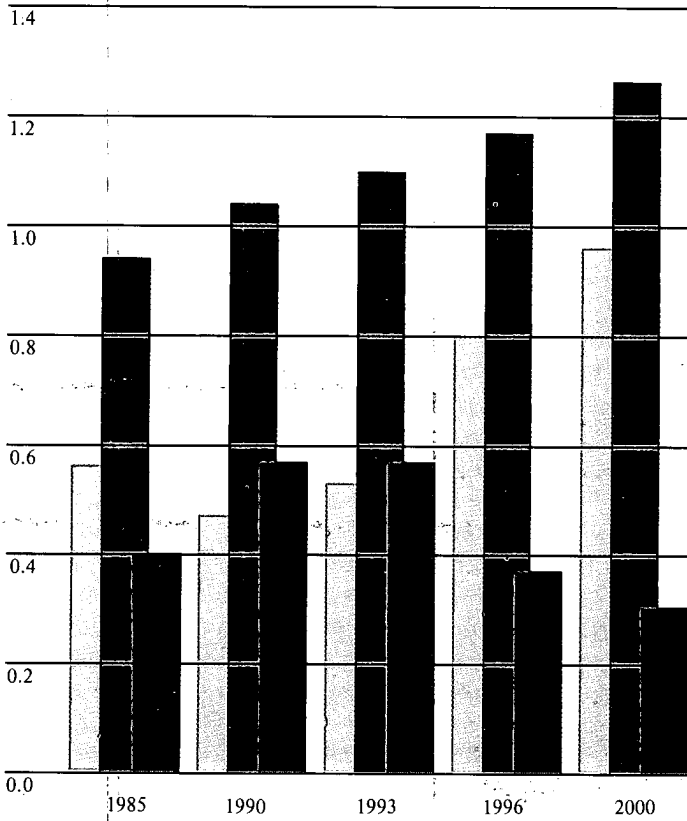
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Figure 3
Brazil's Oil Picture: Delayed Scenario
Development

Oil balance

Million barrels per day

Production Consumption^a Imports

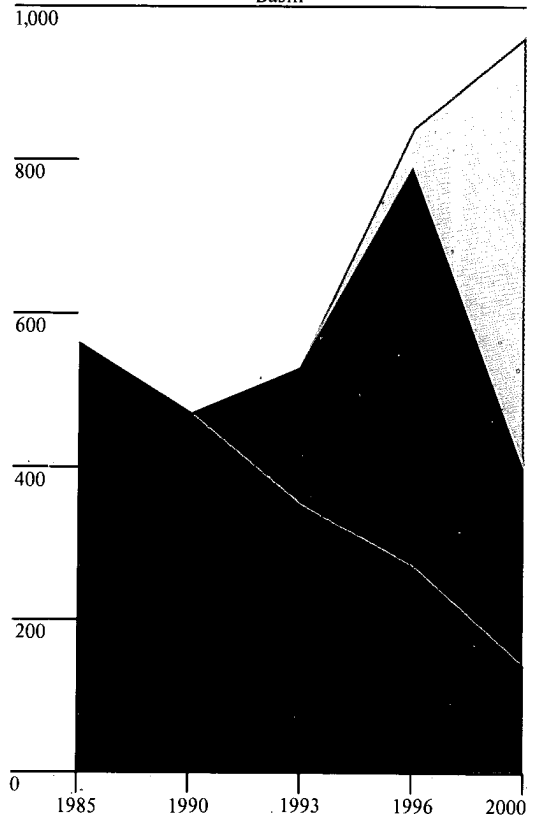


^a Assuming mid-range of consumption forecast.

Sources of oil production

Thousand barrels per day

Future discoveries New Campos Basin Existing fields



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***Slower Development Scenario:
Possible Fallout From
Falling World Oil Prices***

There is currently debate among Brazilian officials regarding the size of future funding for Petrobras. Although energy security remains a priority, falling world oil prices lessen the urgency for investment in oil exploration and development. Moreover, other state-owned companies involved in the railroad, power, and mining and minerals industries are competing with Petrobras for financial assistance. As a result, civilian leaders may elect to reduce investment in the oil sector until market conditions tighten and to channel available funds to other sectors of the economy. Petrobras also may be increasingly asked to pay royalties to the state and municipalities in which oil is found; this could further constrain available funds for exploration and development.

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To reduce Petrobras' annual investment outlays, Brasilia could choose to develop the new Campos Basin fields at a slower rate and reduce the pace of exploration drilling. Given Brazil's oil requirements, however, we do not believe Brazilian planners would delay reaching full production from these fields beyond the mid-1990s, compared with the early 1990s in the likely scenario. If this approach is taken, Brazilian oil production could begin to decline slightly around 1990, as a result of the aging of currently producing fields. A drop in output to approximately 470,000 b/d by 1990 is possible, with an accompanying rise of 200,000 b/d in imports likely. But production would begin to rebound and imports decline slowly in the early 1990s as the new fields come into production. Output could rise to about 530,000 b/d by the early 1990s and to about 800,000 b/d several years later. By that time, allowing for further increases in consumption, Brazil would be about 400,000 b/d short of covering its annual oil needs at the midpoint of our demand estimate (see figure 3). If, in addition, Brazil delayed further exploration in the Campos-Sergipe-Alagoas trend by about three years, we would expect that Brazilian oil production would not reach the 1.0- to 1.2-million-b/d plateau until the year 2000 or later.

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Appendix

Projecting Brazilian Oil Production: A Methodology

The projected oil production for Brazil was obtained by dividing future oil production into three categories: existing production, future production from the new Campos Basin discoveries, and future production from oilfields yet to be discovered. [redacted]

The projected oil production from currently producing fields was calculated by performing decline rate analysis on 27 fields that account for 100 percent of Brazil's offshore production and 66 percent of Brazil's onshore production. This type of analysis is based on the fact that oil production from a field declines at a constant rate once maximum oil production is reached. The decline rate was obtained from field production records and was then applied to the current production rate to obtain the field's future oil production. [redacted]

Future oil production from the onshore fields not included in the individual field analysis was obtained by grouping this production together and thinking of it as coming from one field. The decline rate for this theoretical onshore field was assumed to be the average of the individual decline rates calculated for the other onshore fields. This average onshore decline rate was then applied to the combined current production rate to obtain the future oil production from these fields. [redacted]

The projected oil production from the new Campos Basin discoveries was obtained by calculating the maximum production rate for each discovery. The maximum production rate was obtained by taking into account the size of the field and the engineering parameters of the reservoir rock containing the oil. Our analysis assumed that the new discoveries would reach peak production five years after coming on line and that peak production would last for three years. The engineering parameters of the reservoir were then used to calculate a decline rate for each discovery. The calculated decline rate was then applied to the projected maximum oil production rate to obtain the field's production after peak production was reached. [redacted]

Future oil production from fields yet to be discovered was obtained by projecting the amount of oil that will be discovered in Brazil during the next 10 years, the likely field size of future discoveries, and the maximum production rates and decline rates of the new discoveries. [redacted]

This analysis assumed that approximately 2.5 billion barrels of oil will be discovered in Brazilian offshore basins during the next 10 years, and that onshore discoveries will cushion onshore production declines resulting in a net future onshore production decline of 5 percent. We believe these assumptions are realistic because of the existence of six undrilled structures in the Campos Basin, which could contain up to 1 billion barrels of oil each, and the lack of exploration in the Campos-Sergipe-Alagoas offshore trend that could contain up to 4 billion barrels of oil. The future discovery of large onshore oilfields was considered unlikely in view of Brazil's onshore geology, but any such discoveries would add to the potential established by this analysis. [redacted]

Future offshore discoveries will probably be large. Our analysis assumed that future discoveries are likely to be in the 300-million- to 1-billion-barrel range. For the purposes of this analysis, we assumed that a single billion-barrel field and three 500-million-barrel fields will be discovered offshore during the next 10 years. This analysis is based on the fact that seismic work indicates that untested structures in the Campos Basin are large, and the likelihood that in a period of rapidly falling oil prices Petrobras will only explore structures that have the potential to contain large amounts of oil. [redacted]

The maximum production rates and decline rates of future discoveries were assumed to be the same as those of similar currently producing fields in the Campos Basin. This assumption is justified because future oil discoveries will be in the Campos Basin or in geologically similar basins to the north, and is made because, unlike the new Campos Basin discoveries, engineering parameters of the reservoir rock are not available. [redacted]

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