The Threat of Competition and Productivity*

Benjamin Bridgman† Victor Gomes‡ Arilton Teixeira§

January 21, 2006

Abstract

State owned enterprises (SOEs) tend to perform worse than privately owned firms. However, the reason for the poor results is unsettled with some have emphasizing ownership itself and others the market environment that they face. We study a unique natural experiment: The Brazilian state owned oil company Petrobras lost its constitutional guarantee of a legal monopoly. The main finding of the paper is that the environment publicly owned firms face is a powerful force for improving productivity. Though Petrobras faced little immediate competition, labor productivity growth rate more than doubled with the reform. The results also demonstrate that indicators of market outcomes are often poor proxies of market competitiveness.

*Preliminary. We would like to thanks James Schmitz Jr. for comments and Patrícia Moura da Silva for research assistance. The views expressed in this paper are solely those of the authors and not necessarily those of the U.S. Bureau of Economic Analysis or the U.S. Department of Commerce.

†Bureau of Economic Analysis, Benjamin.Bridgman@bea.gov.

‡Capixaba Research Foundation and UCSD, vgomes@econ.ucsd.edu.

§Capixaba Research Foundation, arilton@fucape.br.

1 Introduction

State owned enterprises (SOEs) tend to perform worse than privately owned firms. (See Megginson and Netter [15] for a survey.) However, the reason for the poor results from SOEs is unsettled. Some have emphasized ownership itself. Public firms may be used to accomplish non-economic goals such as providing patronage to the government's political supporters. (World Bank [1]) The government may be less able to solve agency problems. (Hart, Shleifer, and Vishny [10]) Others have emphasized the market environment that SOEs face. They are often given preferential market access, up to outright monopoly, and protected by trade and entry barriers. (Vickers and Yarrow [20])

We study a natural experiment that shows the importance of the competitive environment for productivity. In 1995, Brazil ended the legal monopoly rights of Petrobras, its state owned oil company, over production, refining, import and export of oil. Petrobras was not privatized or broken up and there are no plans to do so. We show that immediately after this change, productivity growth sharply increased.

There are a number advantages of this natural experiment over the existing literature.

First, we do not have to rely on imperfect proxies, such as market share or import penetration, for competitive pressure. We have a clear change in the competitive environment: Prior to the reform, competition was illegal while afterward it was allowed. In fact, market concentration indicators changed very little after the reform. They would have missed a shift in the competitive environment.

Second, the change is free of a number of confounding effects that other studies encounter. In most cases, reforms are typically part of a comprehensive package, making it difficult to identify how each change affects productivity. For instance, a firm may be privatized at the same time as its markets are liberalized and trade barriers are reduced. Therefore, it is difficult to disentangle the effects of ownership change from those of market changes. We do not have to disentangle the effects of multiple policy changes. The Petrobras reform was simply the removal of a legal monopoly and was not accompanied by any other changes. Ownership was not changed, nor are there plans to do so. Therefore, any changes in productivity cannot

be attributed to other (direct) policy changes.

The main finding of the paper is that the environment publicly owned firms face is an important determinant of productivity. Petrobras's productivity growth improved with introduction of competition. What makes this case particularly compelling, aside from the "cleanness" of the experiment, is that labor productivity growth immediately doubled with the reform despite the fact that it put little immediate pressure on Petrobras. Therefore, not only is environment important but it can be a very powerful force for improving productivity.

The reform lead to a significant increase in productivity growth. Between 1977 and 1993 labor productivity grew at an annual average of 4.3 percent. Between 1994 and 2000 it grew at an annual average of 11.8 percent. Not only did growth more than double, the sources of the growth changed. Labor productivity growth prior to 1995 was due to capital accumulation (with TFP decreasing) while almost all growth after 1994 was due to TFP growth (as capital stock fell).

The increase in productivity growth was swift. With the advent of the reform, Petrobras slashed its use of inputs while maintaining output growth. It also began to shift its portfolio of oil wells to more productive regions. The speed with which the changes were implemented indicate that they were feasible prior to reform (physically, if not politically).

While the size and speed of the increase is notable on it own, they are all the more impressive given how little competition Petrobras actually faced after losing its legal monopoly. It maintains a dominant position. For example, Petrobras still has over 97% of Brazil's refining capacity. Its advantages as a large incumbent made it difficult for competitors to enter the market. Unlike previous studies where firms face a declining market as a result of competition such as Galdon and Schmitz [8], the *threat* of competition was sufficient to generate significant productivity gains.

The results demonstrate the power of a competitive market. There are no plans to privatize the company and it is unlikely to occur in the future given the political sensitivity of such a move. When privatization is not politically viable, increasing competition in the markets of state-owned firms can provide an avenue for improving performance. The results lend support to the view that the competitive environment is an important determinant of productivity, regardless of ownership. (Bartel and

Harrison [2] find similar results for Indonesia.)

The results also clearly demonstrate that indicators of market outcomes are often poor proxies of market competitiveness. The prospect of competition resulted in major changes in Petrobras's management strategy and productivity. However, commonly used market outcome proxies such as concentration indices changed very little with the reform. As a proxy for competition, they would have missed a important shift in the competitive environment.

2 The Oil Industry in Brazil

Since oil was discovered in Bahia in 1938 until the 1990s, the Brazilian oil industry has been characterized by increasing government intervention.[1]

From 1938 to 1954, the government sought to develop the oil sector through private companies while serving as a regulator through the National Petroleum Council (henceforth CNP, from its Portuguese name). But the private sector did not show much interest since the reserves belonged to the CNP and there was no legislation to guaranteing investors the benefits of exploration. In addition, the cost of extracting oil in Brazil was high compared to that of the Middle East.[2]

In 1954, the government created the state-owned monopoly Petrobras to explore, extract and refine petroleum. (Existing private refining companies were allowed to continue operating but could not expand.) This policy was part of a larger import substitution policy to develop the industrial sector (Kingstone [13]).

The monopoly power of Petrobras was extended to the import and export of oil in the 1963. Between the creation of Petrobras and 1970s, domestic prices were essentially equal to the international prices plus a Federal tax. In an attempt to shield the domestic economy from the oil shocks, domestic prices became disconnected from international prices in 1977 and based on a measure of domestic production cost.

In 1988, the process of increasing government intervention reached its apex when Petrobras's monopoly rights were guaranteed in the new Brazilian constitution.

[1] See Campos [5].

[2] See Ministerio das Minas e Energia [6] and Serour [18].

By the beginning of the 1990s, the process of privatization and deregulation in the Brazilian economy reached the oil sector. A constitutional amendment (Constitutional Amendment Number 9) approved by the Brazilian Congress in 1995 ended the monopoly rights of Petrobras over production, refining, importing and exporting of oil. Though many other sectors were privatized, the Brazilian government did not propose privatizing Petrobras. The end of monopoly was the biggest concession that the government could manage to get from the Brazilian Congress[3].

With the change in the Brazilian constitution, a new regulatory framework was set up for the oil sector. In September 1997, a new law was approved by the Congress allowing any firm to produce, transport, refine import and export petrol in Brazil. In 1998, two government decrees set up a regulatory structure in the sector and the National Energy Policy Council (CNPP) to advise on the norms and rules for the sector. It created the National Petroleum Agency (ANP henceforth) to regulate the sector. Finally, it set up auctions to sell the rights to extract oil in Brazil. In 1998, Petrobras were given the rights to the fields it has already started exploiting, keeping 7% of potential areas. This was called Round 0. In 1999, auctions began to sell exploitation rights for the remaining areas (Kingstone [13]).

3 Productivity at Petrobras

In this section we will analyze Petrobras's productivity performance in response to the loss of its legal monopoly.

Even though the change in the monopoly status of Petrobras happened in 1995, discussion of the policy change began earlier. When dating the beginning of a reform, the date of the legal change may not be the most relevant date. Managers in the reformed industry may have anticipated the reform and introduced changes prior to the reform becoming official. (This is sometimes called the "announcement effect.")

In a study of the impact of privatization in the Brazilian iron ore sector Schmitz and Teixeira [17] argue that 1989 should be set as the beginning of the reform. It was in 1989 that a new Brazilian president was elected promising to privatize and

[3]Kingstone [13] explains in detail how President Fernando Henrique Cardoso overcame opposition in the Congress to end the constitutional monopoly rights of Petrobras

deregulate the economy to increase competition (Kingstone [13] and Velasco [12]).

We date the beginning of the reform in the oil industry as 1994. The policy to remove the monopoly originated with President Fernando Henrique Cardoso, who took office in January 1994. In January 1995, he sent an amendment to the Congress (Amendment #9) to eliminate Petrobras's monopoly and Congress approved it in September 1995. Since discussion began before the amendment was sent to the Congress, we argue that 1994 is the year that the reform of Petrobras began.

In what follows, we will argue that the end of Petrobras's monopoly rights and the threat of new competitors had a impact on its productivity performance. First, we will look at a measure of technological progress, total factor productivity (TFP), of Petrobras. TFP is computed using a Cobb-Douglas production function given by

$$Y_t = A_t K_t^{\theta} M_t^{\alpha} N_t^{(1-\theta-\alpha)} \tag{1}$$

where K_t is the aggregate capital stock, M_t is the amount of material, N_t is the number of employees, θ is the capital share, α is the labor share and A_t is the total factor productivity (henceforth TFP).

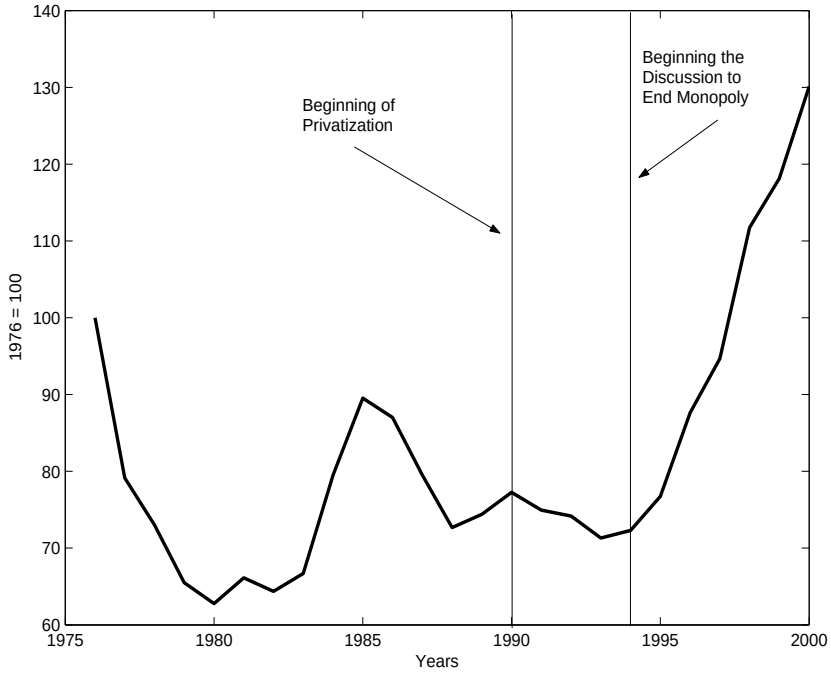
Using the balance sheets of Petrobras and data available at the ANP we computed total amount of oil produced, the capital stock, the number of employees for each year and the labor share in the period 1976 and 2000. The average labor share in the period equal to 0.2 was used as the calibrated value of α. We did not have data for material so we use a proxy. We assume the total amount of material is a fixed proportion of the number of wells. Behind this assumption is the idea that the amount of material used is defined by technology and therefore can not be easily substituted. Using data available for the United States we computed the share of capital equal to 0.45[4] Therefore the share of material was set equal to 0.35.[5]. The results are shown in Figure 1

The second half of the 1970s are characterized by a deep and abrupt fall in TFP

[4]We use the KLEM data set for Oil and Gas Extraction (Industry Group 4) described in Jorgenson and Stiroh [11]. The labor share for Petrobras was nearly identical to that of the United States.

[5]See the Appendix for details on the data

Figure 1: Total Factor Productivity of Petrobras, 1976-2000



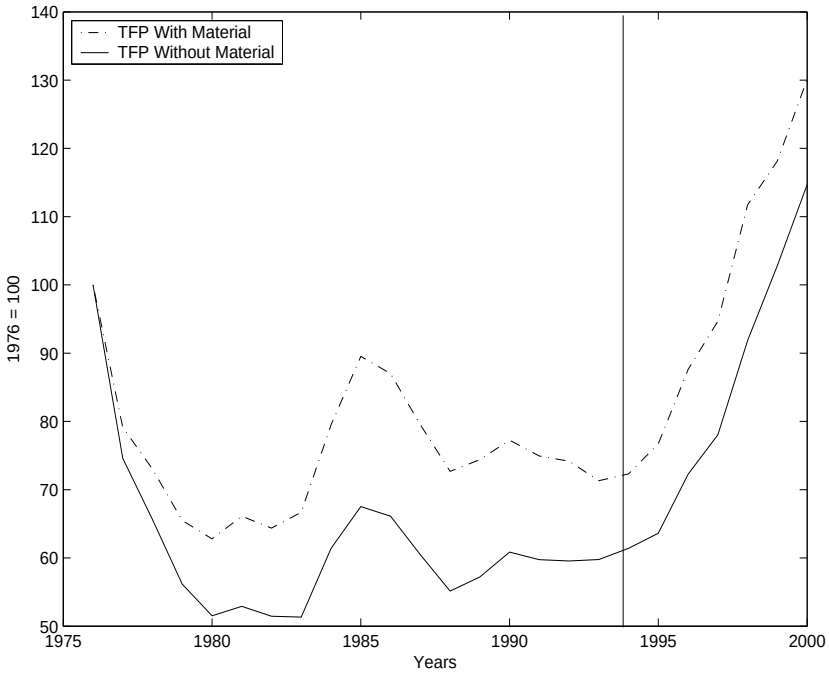
of Petrobras. The TFP index falls from 100 in 1976 to 63 in 1980. This fall in TFP of Petrobras is in line with the fall in the aggregate Brazilian TFP (Bugarin, et al. [4]).

From 1980 until 1993 TFP shows no sustained gains. This period corresponds to the time Petrobras was a legal monopolist. In fact, its monopoly power was increased in this period. On the other hand, from 1994 until 2000 TFP grows very fast. In five years TFP almost doubled, increaing 82%. This is the period when a constitutional amendment abolished the monopoly rights of Petrobras, opening the sector to private companies.

The results shown in Figure 1 could be driven by the assumption about materials. To check this possibility, we assumed that θ, the capital share in Equation 1, was equal to 0.8 and that material share was equal to zero. In this case we do not need to use any proxy for material. The results of TFP computed with and without

materials in the production function are shown in Figure 2

Figure 2: Total Factor Productivity of Petrobras, 1976-2000



Excluding materials changes the magnitude of TFP's movements, but does not affect its pattern. In what follows, we will keep materials in the production function since we know from the U.S. data that materials are an input in the oil sector.

The next step is to study the sources of growth of production and labor productivity (henceforth productivity). First we perform a growth accounting of growth rate of output. Logging Equation 1 and rearranging the terms we have:

$$\begin{aligned}\left[\log\left(Y_{t+s}\right)-\log\left(Y_t\right)\right]/s = \left[\log A_{t+s}-\log A_t\right]/s+\theta\left[\log\left(K_{t+s}\right)-\log\left(K_t\right)\right]/s+ \\ \alpha\left[\log\left(M_{t+s}\right)-\log\left(M_t\right)\right]/s+(1-\theta)\left[\log\left(N_{t+s}\right)-\log\left(N_t\right)\right]/s\end{aligned} \quad (2)$$

The left hand side of Equation 3 gives us the contribution of technological progress,

accumulation of capital, material and number of workers employed to output growth. As we said before, using a capital share of 0.45 and labor share equal to 0.2 the growth accounting in the two subperiods is given in Table 1.

Table 1 - Growth Accounting of Petrobras's Output(%)

Period	change in Y	due to TFP	due to K	due to M	due to N
1977-1993	8.0	-1.8	5.6	0.7	3.5
1994-2001	8.7	8.6	0.3	-0.9	0.7

The growth rate of output increased slightly in the period without monopoly. But the major difference comes from the sources of growth in the two subperiods. In other words, the engine of growth changed. In the first period, output grew almost entirely due to increasing capital and materials. There is no technological progress. In fact technology regressed (see also Figure 1). This result is similar to the the findings of Bugarin, et al. [4] for the aggregate Brazilian economy. They found that to keep the economy growing after the oil shocks of the 1970s the government encouraged capital accumulation, despite the lack of technological progress. Trying to keep the growth rate of the Brazilian economy the government subsidized private companies and had SOEs, like Petrobras, leading these companies to increase investment. (We elaborate on this point below.).

In the second subperiod, the major source of growth is TFP. The growth rate of TFP increased dramatically and it explains 99% of the growth rate of output.

We also performed a growth accounting of productivity (labor productivity). We divide Equation 1 by N_t than take logs and rearrange the terms to get

$$\left[\log\left(\frac{Y_{t+s}}{N_{t+s}}\right) - \log\left(\frac{Y_t}{N_t}\right)\right]/s = \left[\log A_{t+s} - \log A_t\right]/s + \tag{3}$$
$$\theta\left[\log\left(\frac{K_{t+s}}{N_{t+s}}\right) - \log\left(\frac{K_t}{N_t}\right)\right]/s\alpha\left[\log\left(\frac{M_{t+s}}{N_{t+s}}\right) - \log\left(\frac{M_t}{N_t}\right)\right]/s$$

Using the same capital share and the share of material as specified above (θ equal to 0.45 and α equal to 0.35) we get the following results.

Table 2 - Growth Accounting of Petrobras's Labor Productivity (%)

Period	change in Y/N	due to TFP	due to K/N	due to M/N
1977-1993	4.3	-1.8	3.9	2.2
1994-2001	13.4	8.6	2.4	2.4

Table 2 gives us a better idea of the engine of growth. First, we see that growth rate of productivity more than doubled after the end of monopoly. In the first subperiod, productivity grew almost completely due to an increases in K/N and M/N while TFP fell. In the second, TFP became the major source of growth.

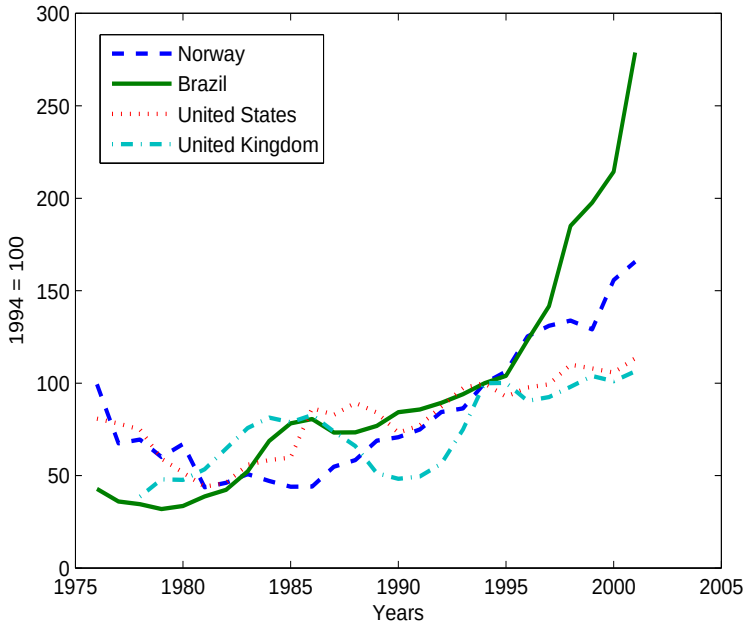
Though the increase in TFP coincides with the change in competitive environment (Figure 1), it is possible the increase was the result of improved oil extraction technology after 1994. To eliminate this possibility, we compare the Brazilian industry to that of the United States, United Kingdom and Norway. If technology advanced faster after 1994 the relative productivity should not change. We would expect the oil industries in other countries to implement the new technology and experience the similar growth in the labor productivity.

Norway's and UK's oil industries resemble Brazil's since they extract oil from deep water wells. The United States also extracts some oil from deep water but much comes from land-based sources. Therefore, the comparison should control for both general technological change in extraction that would affect all countries and specific change that would only affect deep water extraction.

We do not have enough data to compute TFP in the Norwegian and UK oil industries or the U.S. industry beyond 1996, so we examine labor productivity.

Figure 3 plots labor productivity (indices set to 100 in 1994) for the four countries. While there are clearly some differences in the year to year movements of productivity for the four countries, the overall pattern is similar prior to 1994. Productivity falls in the late 1970s and begins to grow in the 1980s. The magnitude to the growth

Figure 3: Oil Extraction Labor Productivity - Brazil, Norway, UK and the United States (Index 1994=100), 1976-2001



from the 1980s to 1994 is similar for all four countries. After 1994, Brazil begins to strongly outperform the other three.

To examine the relative performance of Brazil, Table 3 recalculates Table 2 for four subperiods. Since we are just interested in the Brazilian case we will focus our analysis in this case.

Table 3 - Growth Accounting of Petrobras's Labor Productivity (%)

Period	change in Y/N	due to TFP	due to K/N	due to M/N
1977-1980	-6.4	-11.5	5.6	-0.5
1981-1985	16.4	6.8	6.5	3.1
1986-1993	2.0	-2.1	1.2	2.9
1994-2001	13.4	8.4	2.6	2.4

In the first subperiod, Brazilian productivity relative to other countries is constant. Labor productivity declines everywhere. Looking at Table 3 we see that Petrobras's productivity did not fall as much as TFP because the growth of capital and materials per worker compensated.

In the second subperiod, 1981-1985, Brazilian productivity increased faster than anybody else There are two main sources of growth. Both TFP and the K/N ratio increased. Even though TFP was growing rapidly, more than 59% of the growth of labor productivity is due to the rising K/L and M/N.[6]

In the third subperiod, from 1986 until 1993, except for the UK, productivity is growing at similar rate. Note that Petrobras's productivity is growing only due to rising K/N and M/N. TFP shows a negative growth rate. One possibility to explain this negative growth rate is the increase in barriers to entry in the oil sector. The new constitutional guarantee in 1988 reduced the amount of competition Petrobras's managers anticipated, since changing the constitution is more difficult than changing a law.

Finally, in the last subperiod from 1994 until 2001, Brazilian productivity grows much faster than the other. As noted above, the main change with respect to the growth observed in the period 1981-1985 is the engine of growth. Between 1981 and 1985 the main source of growth is the increase in capital and material per worker. After 1994, TFP is the main source of growth. Besides, there is not any new field whose production could explain the growth rate of productivity as the the beginning of the 80s with the production in Campos.

[6]One reason that could explain the rapid growth of TFP in this period is that production in Campos, a more productive field, began.

4 Competition and Productivity

In this section, we examine the implications of the results for relationship between competition and productivity. We argue that the results show that the *threat* of competition, even absent actual competition, can increase productivity. We discuss the implications of this finding for studying competition and designing reforms.

The reform we study is notable for how minimal it was compared to its effects. Even though Petrobras lost its *de jure* monopoly, *de facto* Petrobras is still a monopolist, particularly in the refining and import sector[7] (Palacios [16] and Lewis [14]).

There was very little entry into the oil extraction market. Table 4 shows the number of fields that Petrobras and other companies bought in each round that took place since 1998. The last column shows that share of all fields purchased over the period. Petrobras has at least an interest in nearly three quarters of new concessions. Even though the number of areas bought by other companies has increased, they have had little success discovering oil. According to Kingstone [13], this has been used as an indicator that Petrobras kept all the most promising areas in Round 0.

Table 4 - Purchase of Rights of Exploitation 1998/2004

Measuring Entry – Number of Fields								
	1998	1999	2000	2001	2002	2003	2004	*Share 98-04 (%)*
Petrobras	96	1	0	7	3	85	57	*54.5*
Petrobras with others	0	6	11	7	5	0	50	*17.3*
Others	19	5	10	19	13	16	47	*28.2*
Total	115	12	21	33	21	101	154	*100*

Source: ANP

Petrobras also has nearly all the refining market. Table 5 shows the percentage of

[7]There is still barriers to entry and the sector is quite risky due to government intervention. For example, currently the Brazilian government is blocking a price increase in the domestic market in response to the high prices of oil in the international market.

Petrobras in the total refining capacity between 1997 and 2003. Petrobras has 98% of the Brazilian installed capacity to refine oil during the entire period. The end of the monopoly did not affect Petrobras's share in the industry. (Though refining is a specific sector of the industry, these figures do not change if we look at other sectors of the industry: production, export, import, distribution[8]. See Lewis [14] and Ellsworth and Gibbs [7]).

Table 5 - Share of the Installed Refining Capacity 1997/2003 (%)

Period	1997	1998	1999	2000	2001	2002	2003
Petrobras	98.7	98.7	98.5	98.6	98.6	98.3	98.4
Other Companies	1.3	1.3	1.5	1.4	1.4	1.7	1.6

Source: Anuario Estatistico (ANP).

An implication of the analysis is that economists should be cautious when using market shares as a indicator of competitiveness. The prospect of competition resulted in changes in Petrobras's productivity. However, market concentration indicators changed very little. As a proxy for competition, they would have missed a shift in the competitive environment.

One of the most popular indices of concentration of firms in an industry is the Herfindhal-Hirschman Index (HHI). It is given by the sum of the square of the market share of all companies in a given industry. It lies between zero and one, higher numbers indicating more concentration in the industry. Using the data in Table 5 we computed the HHI.

Even though we do not have data covering the period before 1997, when Petrobras was a monopolist, it could not be far from the numbers shown in Table 6 since the

[8]Maintaining control of exploration and refining gives Petrobras control of the gasoline market. There is little international trade in gasoline since it must be formulated to local standards, which prevents taking full advantage of economies of scale in transportation.

upper bound for HHI is one.[9]

Table 6 - Herfindhal-Hirschman Index (HHI) in the Refining Sector 1997/2003

Period	1997	1998	1999	2000	2001	2002	2003
HHI	0.97	0.97	0.97	0.97	0.97	0.97	0.97

The HHI was unchanged and showed a extremely concentrated market over the reform period. Using the HHI, one would conclude that the reform was a failure since Petrobras did not cede any of its market share. However, it was successful in increasing productivity. Studies using market share data will miss threats of competition, which can have real effects.

Another implication is that privatization is not be required to improve the performance of public enterprises. There are no plans to privatize Petrobras and it is unlikely to occur in the future. Petrobras is one of a set of politically sensitive state enterprises, called the "Crown Jewels." It is also a significant source of revenues for both state and Federal governments. The removal of the monopoly guarantee alone generated significant political conflict. (Kingstone [13])

The results lend support to the view that the competitive environment is an important determinant of productivity, regardless of ownership. In fact, many instances when only ownership was changed have not resulted in an improvement in performance. (Bartel and Harrison [2]) When privatization is not politically viable, increasing competition in the markets of state-owned firms can provide an avenue for improving performance.

[9]Since 1954, four private companies have operated in the refining sector. They were allowed to operate since they were operating prior to the creation of Petrobras (Serour [18])

5 Sources of Productivity Growth

Since TFP growth increased so dramatically, it is natural to ask what the sources of that growth were. There is evidence that inputs were used inefficiently prior to the policy change. With the loss of its monopoly, Petrobras quickly reduced its use of inputs while continuing to expand output. As shown in Table 1, output grew at similar rates before and after the policy change. Since other countries do not show similar productivity gains, it does not appear that the introduction of new technology lead to the increase in productivity.

There is evidence of overstaffing. Figure 4 shows the number of employees. While employment was declining prior to the loss of monopoly status, the rate of decline increases sharply in 1994. The data are consistent with Petrobras employing more workers than required to produce its output, either for specific patronage reasons or to increase employment generally.

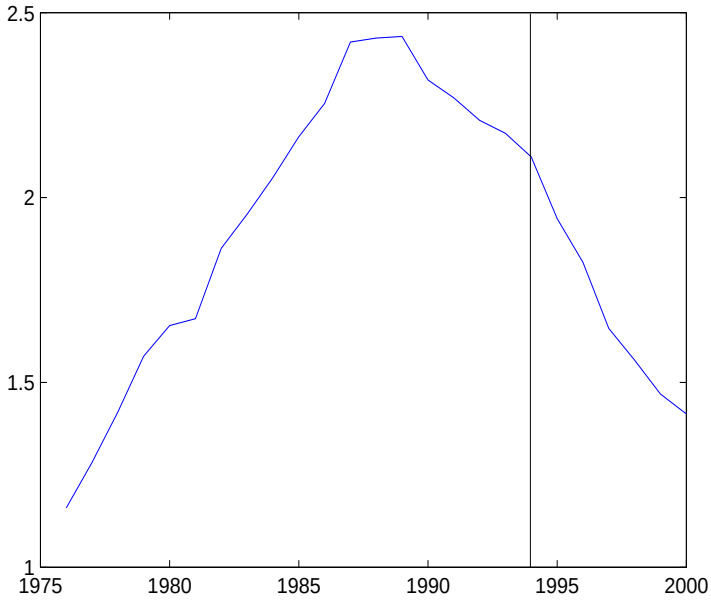
There is evidence that Petrobras's policies were influenced by political considerations. Geddes [9] argues that Petrobras began to be used for political purposes in the 1960s, while it had been relatively unpoliticized before. Management power was given to the oil workers' union to garner political support of the employees. Also, firm funds were used for political purposes. In the early 1990s, the firm was implicated in the corruption scandals that drove President Collor from office. (Valenca [19])

There is also evidence that low quality wells were kept in production prior to the policy change. Figure 5 shows the number of wells in production. Prior to 1994, the number of wells increased steadily. In 1994, wells in production decline (sharply) for the first time in the period covered.

The decline in wells coincides with a large increase in well productivity. Figure 6 show output per well. Petrobras seems to have removed poor wells from production and concentrated its efforts on the best wells. These marginal wells may have remained in use to spread production (and the associated employment, tax revenue and other advantages of local production) over a wider geographical area.

The geographical distribution of wells does change after the reform, with the number of wells in less productive areas declining. In particular, the number of wells in the State of Bahia, a state with some of the least productive wells, fell sharply

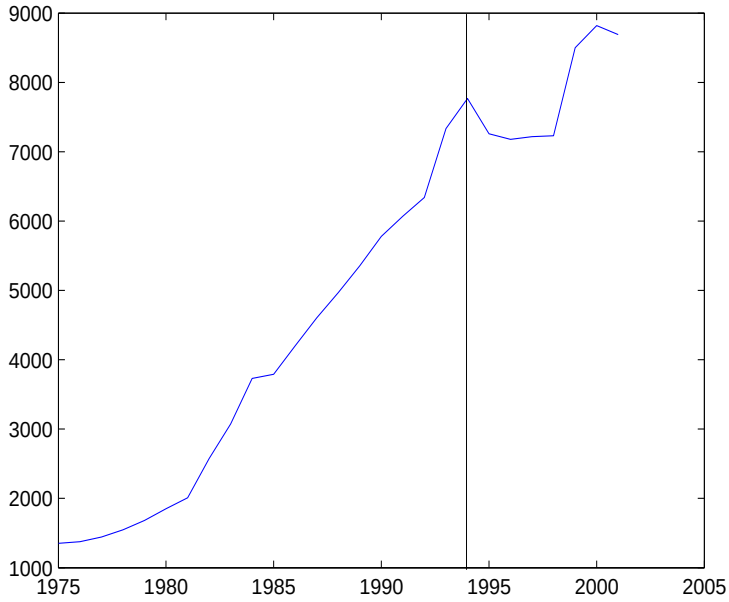
Figure 4: Number of Workers (in 10000s), 1976-2000



while production has largely shifted to more productive areas. In 1994, wells in Bahia produced an average of 9,300 barrels a year while wells in the State of Rio de Janeiro (where high quality Campos reserves are located and a large source of increase in production since the reform) produced an average of 402,000 barrels a year. Figure 7 shows the number of wells in Brazil and the state of Bahia. Prior to the reform, the number of wells in both were growing at the same rate. After the reform, the number of wells declined with much of the decline coming in Bahia: From 1994 to 1995, total wells declined by 509 while Bahia's wells declined by 419. Bahia is a politically important state so maintaining production there may have been politically motivated.

The rapid change in the use of inputs in the absence of major technical change or changes in factor prices suggests that the goals of Petrobras's managers changed with the loss of monopoly rights. The evidence is consistent with non-economic goals,

Figure 5: Number of Wells in Production, 1975-2001



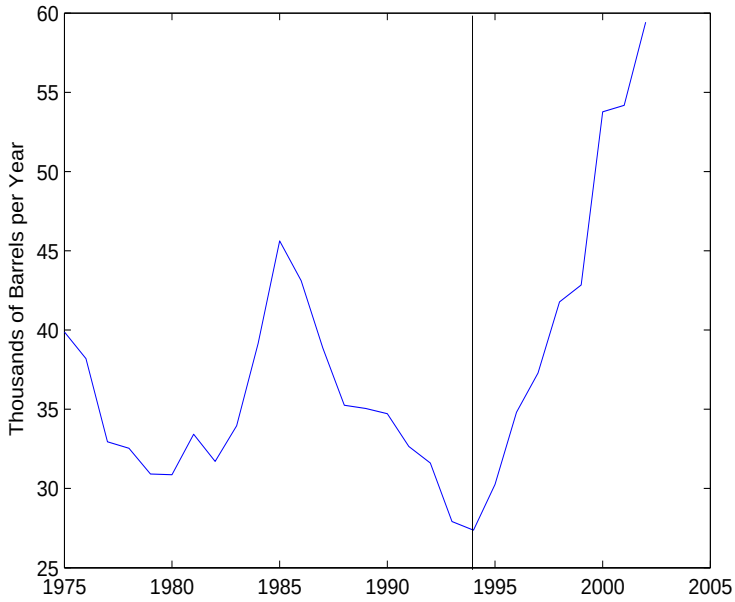
such as spreading tax revenue across a wider base, becoming less important relative to the economic goals of reducing costs and increasing productivity.

6 Conclusion

It is often suggested that protection reduces efficiency. It is also argued that public enterprises are less efficient than private enterprises. The study of the end of monopoly of Petrobras that give us some insights into this topics.

First, some caution is necessary when using market shares as a indicator of competitiveness. As we saw just the threat of competition resulted in changes in Petrobras's productivity. However, market concentration indicators changed very little. As a proxy for competition, they would have missed a shift in the competitive environment.

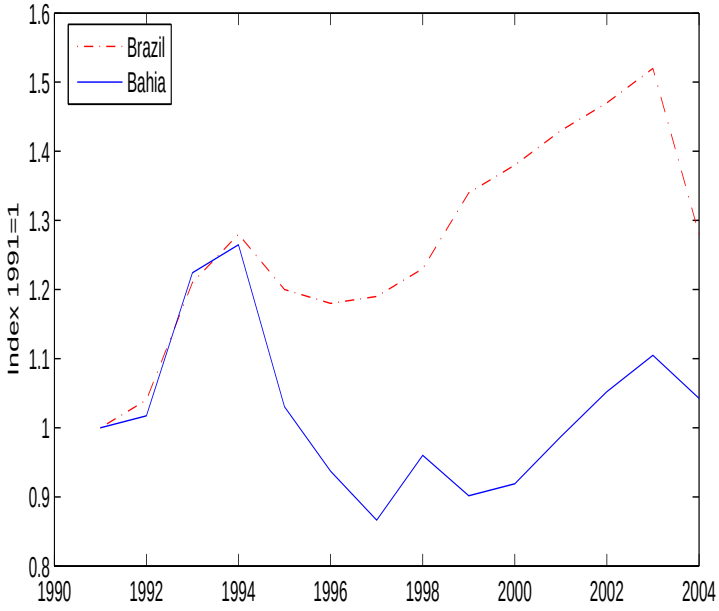
Figure 6: Output Per Well in Production



Second, when privatization is not politically possible, increasing competition in the markets of state-owned firms can provide an alternative for improving performance. The evidence supports the view that the competitive environment is an important determinant of productivity, regardless of ownership.

Third, the results provide support for the idea that closing off competition in the 1970s contributed to Brazil's poor economic performance in the 1980s. Petrobras is a microcosm of the aggregate Brazilian economy. As documented in Bugarin, et al. [3, 4], Brazilian TFP began to fall after the government expanded state-owned enterprises (including Petrobras) and raised trade barriers during the 1970s as a strategy to keep the economy growing despite the worldwide recession and productivity slowdown. While from 1968 to 1974 the economy had grew rapidly due to surging TFP growth, after 1974 TFP began to fall. The Brazilian government tried to maintain the economy's growth rate by boosting the accumulation of capital by

Figure 7: Number of Wells in Production, Brazil and Bahia 1991-2004



subsidizing private investment, having SOEs maintain high investment rates, and increasing protection from foreign firms. From the late 1970s until the early 1990s, the Brazilian economy grew only due to capital accumulation which is also true of Petrobras. The Brazilian economy started recovering after reforms such as privatization and trade liberalization. Bugarin, et al. [3, 4] argue that Brazil's falling TFP in the 1970s was due to the closing off of competition. The findings give support to this argument. While the study of a single industry, even a large one like oil, cannot definitely answer whether restricting competition reduced TFP, it suggests that this is a fruitful avenue of inquiry.

References

[1] World Bank. *Bureaucrats in Business*. Oxford University Press, 1995.

[2] Ann P. Bartel and Ann E. Harrison. Ownership versus environment: disentanbling the sources of public sector inefficiency. *The Review of Economics and Statistics*, 87(1):135–147, 2005.

[3] Mirta Bugarin, Roberto Ellery, Victor Gomes, and Arilton Teixeira. The brazilian great depression in the 80s and 90s. mimeo, Fundacao Capixaba de Pesquisa, 2001.

[4] Mirta Bugarin, Roberto Ellery, Victor Gomes, and Arilton Teixeira. From a miracle to a disaster: the brazilian economy in the last 3 decades. mimeo, Fundacao Capixaba de Pesquisa, 2004.

[5] Roberto Campos. *A lanterna na popa*. TopBooks, 1994.

[6] Ministerio das Minas e Energia. Setor energetico: destaques em 1999 e oportunidades de negocios. mimeo, Ministerio das Minas e Energia, 2000.

[7] Chris Ellsworth and Eric Gibbs. Brazil's natural gas industry: missed opportunities on the road to liberalizaing markets. mimeo, The James A. Baker III Institute for Public Policy of Rice University, 2004.

[8] Jose E. Galdon-Sanchez and James Schmitz. Competitive pressure and labor productivity: World iron-ore markets in the 1980's. *American Economic Review*, 92:1222–1235, September 2002.

[9] Barbara Geddes. Building state autonomy in brazil, 1930-1964. *Comparative Politics*, 22(2):217–235, 1990.

[10] Oliver Hart, Andrei Shleifer, and Robert Vishny. The proper scope of the government: theory and an application to prison. *Quarterly Journal of Economics*, 112(4):1127–1161, November 1997.

[11] Dale W. Jorgenson and Kevin J. Stiroh. Raising the speed limit: U.s. economic growth in the information age. *Brookings Papers on Economic Activity*, 1:125–211, February 2000.

[12] Licinio Velasco Jr. A economia politica das politicas publicas: fatores que favoreceram as privatizacoes no periodo 1985-94. Discussion Paper 54, Banco Nacional de Desenvolvimento Social, 1997.

[13] Peter Kingstone. The long (and uncertain) march to energy privatization in brazil. mimeo, The James A. Baker III Institute for Public Policy of Rice University, 2004.

[14] Steven W. Lewis. Deregulating and privatizing brazil's oil and gas sector. mimeo, The James A. Baker III Institute for Public Policy of Rice University, 2004.

[15] William L Megginson and Jeffrey M Netter. From state to market: a survey of empirical studies on privatization. *Journal of Economic Literature*, XXXIX:321–389, June 2001.

[16] Luisa Palacios. The petroleum sector in latin america: reforming the crown jewels. Technical Report 88, Les Etudes du CERI, 2002.

[17] James Schmitz and Arilton Teixeira. Privatization's impact on private productivity: the case of brazilian iron ore. Staff Report 337, Federal Reserve Bank of Minneapolis, Research Department, 2004.

[18] Tatyana Serour. Impactos da desregulamentacao sobre o desempenho do setor petrolifero brasileiro, 2003.

[19] Marcio Moraes Valenca. The politics of giving in brazil: the rise and demise of collor. *Latin American Perspectives*, 29(1):115–152, 2002.

[20] John Vickers and George Yarrow. Economic perspective on privatization. *The Journal of Economic Perspectives*, 5(2):111–132, Spring 1991.

A Data

The main source for Brazilian data is the Oil Report ('Relatório do Petróleo') from Ministry of Mines and Energy.

Oil production – thousands barrels per day:

1. Brazil: Oil Report, several years (1954-1990). Anuário Estatístico Brasileiro do Petróleo e do Gás Natural, Agência Nacional do Petróleo, several years (1990-2003).
2. United States: Energy Information Administration, Annual Energy Review, 2001, p. 129.
3. United Kingdom: BP Statistical Review of World Energy, June 2003.
4. Norway
5. World production, includes crude oil, shale oil, oil sands and NGLs (natural gas liquids - the liquid content of natural gas where this is recovered separately): BP Statistical Review of World Energy, June 2002.

Employment – oil and gas extraction, and oil and gas extraction services:

1. Brazil: Oil Report and RAIS. For details about RAIS see De Castro, Gomes e Muendler (2005).
2. United States: Production and Service Jobs and Wells Drilled. U.S. Department of Labor, Bureau of Labor Statistics, National Employment, Hours, and Earnings (*www.bls.gov*). Oil and gas production (eeu10131001), and oil and gas services (eeu10138001).
3. United Kingdom: Employees extraction of mineral oil and natural gas: SIC 92 CA 11. Department of Trade and Industry, UK.[10]
4. Norway:

Oil Prices – prices for oil and for capital goods:

[10]Thanks to Philip Beckett and Mike Earp, Department of Trade and Industry, UK.

1. Dubai, oil spot crude price. US dollars per barrel. 1972-1985: Arabian Light; 1986-2001: Dubai. Sources: Brazilian Oil Report and BP Statistical Review of World Energy, June 2002.
2. Brazil, capital goods: since we don't have investment by type of capital good we apply general prices for capital goods. For this purpose we use wholesale price index that covers domestic and foreign capital goods, *IPA-OG: capital goods* (Indíce de Preços por Atacado - Oferta Global). This price index is from Getúlio Vargas Foundation (FGV – *www.fgv.br*).
3. U.S., equipment goods: Oil and gas field machinery and equipment manufacturing. U.S. Department of Labor, Bureau of Labor Statistics (pcu333132333132).

Natural Gas Prices – prices for natural gas:

1. European Union (cif): 1983-2001. US dollars per million of BTU. Note: cif = cost + insurance + freight (average prices). Source: BP Statistical Review of World Energy, June 2002.

Investment – For investment series, we get the number from the Oil Report (several years) and to 2002-2004 period the numbers came from the 'Orçamento Geral da União' (General Budget from the Union). To get real investment we use the *IPA-OG*: capital goods.

Wages – U.S.: Average weekly earnings of production workers, oil and gas extraction. U.S. Department of Labor, Bureau of Labor Statistics (ceu1021100004).

A.1 Capital Stock

We constructed the capital stock of Petrobras by the accumulation of investment (x). The law of motion for capital stock is:

$$k_{t+1} = (1 - \delta)k_t + x_t \tag{4}$$

where k is the capital stock and δ is a constant depreciation rate. To compute our final capital stock we assume a depreciation rate (δ) of 4% per year. We

start accumulating investment in 1954, so we don't have problems with the initial stock of capital.

A.2 Total Output: Oil and Gas

Typically, petroleum exploration and development yields a joint product: oil and natural gas. The typical way to aggregate oil and gas output has been to convert natural gas to 'oil equivalent' at a fixed ratio based on physical thermal content or on some thermal value content implied by relative wellhead prices at a given point in time. There is a major problem with fixed coefficient. Relative values of oil and gas change over time and this affects the problem of firm (see Aldeman and Watkins 2003).

To adjust our data to this possibility we transform the amount of gas produced into oil, using the price of gas relative to oil in the US spot market (even though the relative price can differ across countries, the variance are very similar. Besides we could not built a series of relative price in Europe due to the lack of data). The intuition behind these procedure is that in equilibrium the marginal rate of transformation of gas in oil is equal to the relative price. Therefore the total amount of oil produced is given by

$$y_t = o_t + \frac{gp_t}{op_t} g_t \tag{5}$$

Where o is the production of oil (thousand barrels day), g is the production of gas (million cubic feet day), op is the oil price (Dubai – barrel price), og is the natural gas price (U.S. natural gas wellhead price – dollars per thousand cubic feet).

References

[0] Aldeman, M.A. and G.C. Watkins. "Costs of aggregate hydrocarbon reserve additions." MIT, mimeo, 2003.