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Effects of Pre-Salt Regulation on the Market Value of Petrobras

Graziela Fortunato, Arilton Teixeira, and Cláudio Bezerra de Mello

ABSTRACT
This article measures the impacts of the process of pre-salt development related to new regulations in Brazil applicable to the offshore pre-salt hydrocarbon reserves. For this purpose, Bai and Perron (2003) and Chow (1960) tests were used to identify structural breakpoints in the behavior of the price of Petrobras stock through a model that includes the ratio of the stock prices of Vale and Petrobras, and the proven oil reserves of Petrobras from 2000 to 2014. The results indicated structural breakpoints in the period of regulation change and when Petrobras issued new shares to raise funds for pre-salt development.

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Oil regulation; Petrobras stock prices; pre-salt reserves; structural break

RESUMEN
Este artículo mide los impactos del proceso de desarrollo del presal, inherentes a las nuevas reglamentaciones aplicables en Brasil a las reservas de hidrocarburos en la zona presal offshore. Con este propósito, se utilizaron las pruebas Bai y Perron (2003) y Chow (1960) para identificar los puntos de ruptura estructural en el comportamiento del precio de las acciones de Petrobrás, mediante el uso de un modelo que incluye la razón de los precios de las acciones de Vale y Petrobras, y las reservas de petróleo comprobadas de Petrobrás de 2000 hasta 2014. Los resultados indican una ruptura estructural en el periodo en que se produjo un cambio en la regulamentación y también cuando Petrobrás emitió nuevas acciones para obtener fondos para el presal.

RESUMO
O presente trabalho mede o impacto do processo de desenvolvimento do pré-sal relacionado à nova regulamentação brasileira que se aplica às reservas de hidrocarbonetos na região offshore do pré-sal. Para tanto, os testes de Bai e Perron (2003) e Chow (1960) foram usados para identificar pontos de derivação estrutural no comportamento dos preços das ações da Petrobrás, por intermédio de um modelo que inclui a razão dos preços das ações da Vale e da Petrobrás, assim como as reservas de petróleo comprovadas da Petrobrás de 2000 a 2014. Os resultados indicaram pontos de derivação estrutural no período de mudança de regulamentação e também quando a Petrobrás emitiu novas ações para captar fundos para o pré-sal.
Introduction

With the discovery of substantial petroleum deposits in the pre-salt geological formations in 2005 and the start of oil production in September 2008 in the Parque das Baleias region (in the part of the Campos basin offshore of the state of Espírito Santo), Brazil’s reserves rose from 14 billion to 33 billion barrels, with the possible existence of between 50 and 100 billion barrels. The sheer size of this potential prompted the Senate Committee on Regulatory Frameworks to make changes to the legislation and regulations applicable to the oil industry. The new rules increased the influence of the Brazilian government—already the controlling shareholder and main stakeholder—on Petrobras.

Until 1995, Petrobras, a government-controlled company founded in 1953, held a monopoly on upstream oil and gas activities. This monopoly was ended by Constitutional Amendment 09/95, and a concession regulatory framework, under the auspices of the newly created National Petroleum Agency (ANP), was subsequently established in 1997 by the Petroleum Law. Under this regime, long-term concessions were auctioned by the ANP in periodic bidding rounds, allowing foreign and domestic companies to obtain exploration and production rights against payment of a signing bonus and royalties subject to a sliding scale based on productivity and profitability. With the confirmation of the pre-salt deposits, a new regime, based on production sharing agreements (still subject to competitive bidding), was established (Oliveira, 2010). The reason was that although the concession model was generally considered successful, having enabled the country’s oil industry to grow significantly and to the point of achieving self-sufficiency, the different reality of the pre-salt reserves was seen by politicians as requiring a new regulatory framework specifically tailored for these areas. The concession regime continues to apply to conventional reserves.

To establish the new regulations, in August 2008 the President Lula administration sent four bills to Congress (07/10, 08/10, 16/10, and 309/09). This initiative was accompanied by a fall in the value of Petrobras shares, due to the perception of increased risk caused by the impending changes in the regulatory regime for upstream activities in the pre-salt areas and further government intervention in the company.

Bill 07/10 defined the creation of the Social Fund, which would use resources from exploitation of the pre-salt reserves for social and technological development in Brazil. A rider to this bill, introduced by Senator Pedro Simon, sought to establish more equal sharing of royalties among the federal, state, and municipal governments.

Bill 08/10, approved by the Chamber of Deputies in March 2010 and the Senate in June that year (becoming Law 12.276/10), established an increase in capitalization of Petrobras and the paid assignment of five billion barrels
of oil to it by the government. Petrobras floated new shares between September 24 and 27, 2010, and raised about US $35 billion to fund new investments. This was seen by the market in general as posing a risk, and increased the company’s cost of capital. The federal government’s stake in Petrobras increased with the paid assignment. Questions were raised about whether the volume of investments and the risks would compromise the return on investment.

Bill 16/10 proposed a new system for sharing the revenues from the pre-salt reserves and other producing fields already being operated under the concession regime, with a more egalitarian distribution among the federal, state, and municipal governments. However, this same basic proposal had been included and vetoed in Bill of Law 07/10, so the bill was tabled.

Finally, Bill 309/09 proposed the creation of a new government-owned company, Pré-Sal Petróleo S.A., or PPSA (originally to be called Petro Sal), and was approved by the Senate in July 2009 and the Chamber of Deputies in November that year, becoming Law 12.304/10. As the name suggests, this company was created specifically to explore and exploit the pre-salt reserves, either alone or in consortiums formed with other companies.

Under the production sharing model, the company that operates the field makes the necessary investments, which are defrayed by the cost recovery oil and/or natural gas, and obtains its remuneration from the profit oil/gas, after the government receives its take from the hydrocarbons extracted, rather than by paying royalties for the right to exploit a concession.

This article investigates the impacts on the stock price of Petrobras of the change in the concession model and the new regulations for the pre-salt reserves. For this purpose, we analyze possible structural breakpoints in the Petrobras stock price series using Bai and Perron (2003) and Chow (1960) tests in a multiple regression model between the ratio of the share prices of the mining giant Vale and Petrobras, the ratio between the main commodities produced by these companies, respectively, iron ore and crude oil (proxied by the Metal Index and Commodity Fuel Index), and the proven oil reserves of Petrobras in the period from 2000 to 2014.

The business literature contains few studies of the effects of the pre-salt reserves in Brazil, since their exploitation is still incipient. However, the literature is vast on the themes of market risk and operational risk. We apply some important findings of this literature to the contents of the bills sent to Congress to verify whether a relationship exists with the fall in the company’s stock price. The market and operational risks, in this case, are associated with the higher government equity stake; the scenario after the new legislation, making the government’s influence even greater than that obtained from the higher equity interest; the need for capitalization for exploration in deep waters; and doubts about the quantity and quality of the oil and gas to be extracted.
The rest of the article is divided as follows: in the theoretical reference section we present the process of ending the upstream monopoly in Brazil; the discovery of the pre-salt reserves; the bills and the functions of the resulting laws; the need for greater capitalization of Petrobras; previous studies; and the risks inherent in the change to the production sharing regime. Then we present the methodology to assess the impact of these four bills sent to Congress on the value of Petrobras’ shares and a possible change in the behavior of the stock price compared to the previous period using the three models mentioned. Next we analyze the results and present our final comments.

**Theoretical framework**

**Relaxation of the upstream monopoly**

Because of the need for huge capital outlays versus scant government budget resources and questions about the efficiency of the monopoly granted to Petrobras, a move to deregulate the hydrocarbon market began in 1990. According to Serour (2003), that year the National Petroleum Council was extinguished and the National Fuels Department (DNC) was created. One of the functions of DNC was issuing licenses to Petrobras and private companies to sell fuels under a contractual or quota regime with the aim of protecting small distribution companies against the market power of large companies.

In October 1995, Constitutional Amendment 9, proposed by the federal government to loosen the upstream monopoly of Petrobras and open the market to foreign companies through concession of exploratory blocks by competitive bidding, was approved by Congress. In this context, the government, holder of the monopoly, sought to provide more flexibility in the activities of exploration, production, importation, exportation, and transportation of oil, natural gas, and their refined derivatives. In August 1997, Law 9 (the Petroleum Law) was enacted, thus ending the monopoly with the aim of attracting foreign investments to develop the sector (Oliveira, 2010). This law ushered in a new phase of opening up the fuels market. Beside the changes in the upstream segment, the Petroleum Law also had impacts on downstream activities by allowing distributors greater access to service stations and making the supply of oil and gas and their derivatives to be a matter of public utility in Brazil.

As provided in the Petroleum Law, in 1998 the National Petroleum Agency (ANP) was created, with the function, among others, of defining mechanisms for granting concessions and authorizations for upstream activities to other companies as well as Petrobras.

The general expectation was that this deregulation would pose Petrobras with difficulties resulting from the loss of its upstream monopoly. However,
the opposite occurred (Bridgman, Gomes, & Teixeira, 2011). Petrobras faced no immediate competition, because there were still no companies in the national market of sufficient size. The simple threat of competition, and even outright privatization, was sufficient to generate productivity gains (Bridgman et al., 2011). According to these authors, the possible reasons for these gains were that (i) the threat of competition and privatization had prompted a change in the company’s priorities, forcing an optimization of inputs (i.e., cuts in excess staffing and transfer of production to more productive wells); and (ii) the economy had expanded strongly in the 1990s (after the “lost decade” of the 1980s, marked by stagnation and high inflation), with many reforms, including opening to foreign trade, monetary stabilization, deregulation, and privatization.

In June 1998, Transpetro (Petrobras Transporte S.A., a wholly owned subsidiary of Petrobras) was created, with main operations in two segments: waterborne transport and pipeline transport of oil, gas, derivatives, and biofuels (ethanol), including terminals. The creation of Transpetro was divided into two phases: absorption of operational management of the ships of Fronape (the largest carrier of crude oil in the Southern Hemisphere) in January 2000 and absorption of the pipelines and terminals in May 2000. Petrobras previously had direct responsibility over both operational activities (Ribeiro & Campos, 2011).

**Pre-salt reservoirs**

Study of the pre-salt reservoirs is relevant because it involves unconventional extraction in deep and ultradeep waters, accessible only after drilling through thousands of meters of underground formations. Recovery of hydrocarbons from these geological formations is thus extremely costly. Nevertheless, estimates are that huge volumes of high-quality oil exist with low exploratory risk (Bridgman et al., 2011).

Petrobras defines the pre-salt formations as the set of rock formations located on the continental shelf along a large part of Brazil’s coastline, from the states of Santa Catarina in the south to Rio de Janeiro and Espírito Santo (Campos basin) in the southeast, with strong potential for extraction of large volumes. The term “pre-salt” is used because the reserves are found in a layer formed by rocks at a depth of between 2000 and 7000 meters that were laid down before the salt layer (Petrobras, 2009).

With the discovery of these reserves, a new model for hydrocarbon exploration and production was envisioned, due to the low exploratory risk, good oil quality, and proven productivity (Bridgman et al., 2011; Oliveira, 2010). This prompted the government in August 2009 to send four bills to Congress to change the model for exploration, production, and distribution of oil, gas, and derivatives in Brazil—Bills 07/10, 08/10, 16/10, and 309/09.
Social fund

Bill 07/10 proposed the creation of the Social Fund, to be regulated by the Financial Management Committee, with the objective of fostering Brazil's social and technological development.

This amendment was vetoed by President Lula, because an agreement had already been reached among representatives of the producing states, congressional leaders, and federal officials calling for distribution of resources from pre-salt exploitation among all the states but without overly harming the main producing states (Rio de Janeiro, São Paulo, and Espírito Santo).

The aim of the Social Fund is to reinvest the revenues from pre-salt extraction in order to (i) improve Brazil's technology; (ii) increase research and development (R&D); (iii) improve university programs; (iv) fight poverty; (v) constitute a long-term public savings fund from federal revenues; (vi) provide reliable funding for social development on a national and local scale; and (vii) reduce fluctuations of fuel prices and income in the Brazilian economy.

The risk envisioned by market participants regarding the creation of the Social Fund is not related to its goals, but rather the possible mismanagement of the resources by the government.

The capitalization of Petrobras and paid assignment

To invest in technology for exploration of deep waters, Petrobras needed further capitalization. For this purpose, the government authorized it to float new shares in a program that brought in about US $35 billion. In turn, the government paid for its portion of the capital increase with the paid assignment of five billion barrels of oil extracted in the future from the pre-salt reservoirs, as provided in the law resulting from Bill 08/10.

The capitalization occurred through a public offering of new shares in the national and international markets. Each common share in the domestic market fetched R $29.65 while each preferred share sold for R $26.30. In the international market, the respective prices were US $34.49 and US $30.59. To boost domestic demand for the shares, the law authorized citizens to use up to 30% of the balance in their FGTS² accounts to buy shares.

Although the offering raised R $115.5 billion (US $66.9 billion), Petrobras used about 68% to pay for the assigned barrels of oil and only 32% to finance capital expenditures.

The federal government, the company's main shareholder with 32% of the total capital and 64% of the common shares, would have had to spend a huge amount to participate in the capital increase and maintain its equity stake. Instead, it opted for the paid assignment strategy, assigning five-billion barrels of future oil from the pre-salt reserves in the Santos basin, belonging to the
government (Assis & Araújo, 2011). Payment for the oil by Petrobras was in federal bonds, at market value (Senado Federal, 2010a).

The value of the paid assignment in the capitalization of Petrobras was US $42.533 billion, or R $74.807 billion, corresponding to five billion barrels of oil—US $8.51 per barrel extracted from the pre-salt deposits—paid for in federal bonds. This value was defined by the National Energy Policy Committee. With this transaction, the government increased its stake in Petrobras without having to spend budget resources or issue new bonds. More specifically, along with the National Bank for Economic and Social Development (BNDES) and the Sovereign Fund, the government raised its share in the total capital from 40% to 48%, increasing the risk of interference in the company’s future yields, besides revealing the high price paid for the pre-salt exploitation rights.

Therefore, the need to capitalize the company was due to the high investment required for deep water extraction technology, the cost of acquiring the rights to exploratory blocks in the pre-salt areas, and the need to continue the 2010–2014 business plan. All this was perceived as risk, thus increasing the company’s cost of capital.

**Pré-Sal Petróleo S.A.**

Pré-Sal Petróleo S.A. (PPSA) is a state-owned company with no formal link to Petrobras, established to represent the government in production sharing agreements, assure the lowest cost with the highest profit under those contracts, and generate additional revenue. PPSA is subordinate to the Ministry of Mines and Energy and responsible for administering the new contracts for the sale of oil and gas from new reserves.

PPSA was not created to assume risks or make investments; therefore, it does not make profits from the extraction of hydrocarbons or have any operational assets. The National Energy Policy Council sets the blocks to be put up for auction, with the invitations to bid and model contracts being drafted by the Ministry of Mines and Energy (MME) under the aegis of the ANP. Upon the announcement of the winning bidders, the MME signs the contract in name of the government and sends information to a committee formed of industry representatives, including Petrobras, and representatives of the government. The chairperson of the committee, a PPSA representative, has voting rights and veto power.

Petrobras is a mandatory participant in all consortiums formed to explore and exploit pre-salt blocks, with minimum share of 30%, making it the only operator to participate in all blocks. The government can also delegate the exploitation of a block to Petrobras without a public tender and hire it to carry out the exploratory studies that precede auctioning of areas under the production sharing system. This exclusivity demonstrates the heightened
influence of the government in Petrobras and how it can intervene more forcefully in the company’s decisions. This insecurity and risk resulted in a decline in the value of the company’s shares before the full brunt of the 2008 crisis and a delay in their recovery after the crisis compared to the general market.

Transition from the concession regime to the production sharing model

The main change of the new framework for the pre-salt reserves is the transition from the concession model to the production sharing model, which provides for greater government participation in exploration and production activities. Under the concession regime (still applicable to conventional fields), companies acquire the right to explore an area by payment of a signing bonus plus royalties (including an “extraordinary participation” in the case of particularly profitable discoveries).

Under the production sharing regime, the hydrocarbons remain under government ownership and the companies defray their expenses and obtain profit through shares of the output, respectively called the cost recovery and profit oil/gas (Barbi & Silva, 2008). In this model, a consortium of companies carries out the exploitation and production activities, with each assuming the risk according to its participation. In case of success, the consortium will receive payment through oil and/or gas, both to cover the investment and obtain a profit, with percentages defined in each contract. This percentage of sharing between the government and consortium is one of the criteria for selecting the winning bidders in any auctions, with the minimum set by the government in the invitation to bid.

The production cost is subject to prior approval of the government and is monitored by PPSA. For the pre-salt areas and new conventional areas designated as of strategic importance, the contracts are awarded through auctions or directly, with Petrobras.

The production sharing model is usually adopted by countries that do not have a well-structured tax regime, requiring the creation of a state-owned company to administer and oversee exploration and production (E&P) activities. This model is not transparent, since the purchasing of goods and services is done after adoption of the model. In Norway, for example, there are no auctions to choose the companies for upstream activities: selection is at the government’s discretion.

The option for the production sharing model in Brazil required changes in the law which can lead to uncertainties and insecurity, thereby decreasing willingness to invest. Negative consequences on exploration and production include delays in the startup of extraction from pre-salt reservoirs and possible adverse effects on Petrobras stock prices. This model has attracted criticism from some observers, whose main argument is that because the existing legal framework is internationally accepted, any change can reduce interest from foreign investors.


Previous studies

Studies dealing with the government’s influence in companies focused on the effects on financial and economic performance (Boubakri, Cosset, & Saffar, 2008; Lazzarini & Musacchio, 2010), on financial leverage (Dinç, 2005; Lazzarini & Musacchio, 2010; Sapienza, 2004; Thomsen & Pedersen, 2000), and on firm value (Borisov, Goldman, & Gupta, 2015; Faccio, 2006; Firth, Gong, & Shan, 2013.) It is expected that any interference, given the status quo, will bring benefits to business performance. However, this is not always observed. The government interference may be favorable to domestic companies but not the market as a whole when it creates protectionist rules or barriers to foreign firm entries in the domestic market that hamper competition. Regulation, needed to control certain activities of the economy, utility companies, for example, is also a government interference that can trigger consequences on stakeholders (Costa, Costa, Baptista, & Antunes, 2009). Regulation can also influence investment decisions (Nagel & Rammerstorfer, 2008). Dixit (1991) and Dixit and Pindyck (1994) studied the impact of price control through real option methodology and found that regulatory interventions lead to disincentives for investment besides and higher external risk (Nagel & Rammerstorfer, 2008). Hence, when the government is a shareholder, negative effects on business were also observed in Europe, both in profitability and market value. The government may have social objectives that are unaligned with private companies when deciding to control prices, create jobs, or develop specific regions (Thomsen & Pedersen, 2000). One example of price control is the case of the Brazilian energy sector, with Provisional Measure 579 (Sauer, 2015). Likewise, Procianoy and Carvalho Sobrinho (2001) analyzed the effects of privatization in Brazil, where companies became more efficient and profitable. These results were in line with Anuatti-Neto, Barossi-Filho, Carvalho, and Macedo (2005), since after the privatization of telecommunications companies, profitability, and operational efficiency increased. Schmitz and Teixeira (2008) also found that the privatization increased productivity in the iron ore industry. They also said that productivity gains from privatization are much more general and widespread than has been recognized in the literature.

The loss of government financial support was also favorable due to the impact on the financial structure of the companies since current liquidity increased and long-term debt was increased. In this case, reduction of government participation was considered as positive for businesses.

Brey, Camilo, Marcon, and Bandeira-de-Mello (2014) observed that Brazilian companies decided to adopt a corporate political strategy, with either be direct (shareholder) or indirect (pension funds) government involvement, thereby providing a mechanism for influence in company decision-making.
**Risks**

Risk arises from uncertainty about future events and can be calculated based on probability and statistics, (Damodaran, 2007), treating variance as a risk measure, as originally proposed by Markowitz (1952). Of the several definitions of risk, some focus on the likelihood of negative events while others consider the consequences of these events. Other interpretations consider both gain and loss. The tradeoff of risk/return is at the core of the definition of risk (Damodaran, 2007).

Gitman (1997) defined risk as the possibility of financial loss, or more formally classified the word risk as the uncertainty over the variability of returns generated by an asset. Further according to Gitman (1997), assets exposed to greater possibility of losses are viewed as more risky in comparison with those with lower likelihood of losses. When acquiring a company’s shares, the investor of course hopes for good earnings, but must figure in the risks of market fluctuations.

There are basically four types of risk to which all companies are exposed: operational risk, market risk, credit risk, and liquidity risk (Ross, Westerfield, Randolph, & Jaffe, 1995).

Risks can be further classified among those originated in the company and those of external origin; thus, although internal risk can be managed, external risk cannot. Risk can also be classified as business or financial, that is, the ability of a bond issuer to repay. In the same way, financial institutions recognize six types of risk, thus, in addition to the four mentioned, legal risk and image risk (Bergamini Junior, 2005).

According to Crouhy, Galai, and Mark (2001), even operational risks can be classified in two categories, internal and external. The first is associated with the deficiency of internal controls, mainly resulting from failures by personnel, technology, and processes. The second is associated with events outside the company’s control, albeit still manageable, such as the risk of choosing a determined strategy and then facing subsequent changes in environmental factors. According to Deloach (2001), operational risk represents the chance that operations will be inefficient or ineffective in executing the company’s business model, satisfying the needs of customers, or meeting quality, cost, and performance standards. Saunders (2000) stated that operational risk can arise any time the existing technology fails to function adequately or when new support systems fail.

In the case of Petrobras, there is the possibility of increased operational risk due to the need for capitalization to acquire resources and technologies for deep-water exploration and production. This is an internal risk, due to the uncertainty over the cost of the new technologies, the time to develop them, and the economic feasibility of future projects. Analogously, the uncertainty over discovery of new pre-salt fields can be characterized as an external risk, also affecting the market risk.
Analysis of the market value of Petrobras during the change in the legal regime indicates slow recovery of the stock price in relation to other companies after the 2008 crisis. This effect can be associated with the uncertainties caused by (i) the new scenario, due to the need for further capitalization to fund exploration and production in deep waters, which might still prove insufficient and entail additional capitalization transactions; (ii) the legal changes that require the company to participate in all the consortiums formed for new pre-salt exploratory blocks; (iii) the paid assignment of five billion barrels of oil, not yet extracted, thus increasing the governments’ participation and enabling greater intervention, particularly with the production sharing model; and (iv) uncertainty about the quantity and quality of the hydrocarbons to be found and the high extraction cost.

On the other hand, the capitalization provided much-needed funds to develop new technologies and implement its 2010–2014 business plan. According to Damodaram (1999), higher rates of growth, return on equity and return on assets are potential benefits of capitalization that can bring returns that exceed the market interest rate after calculating the tax deductions from debt service. Further, when Petrobras lost its monopoly on upstream activities, the threat of competition (and also of privatization) prompted the company to change its priorities and optimize inputs by reducing excess staffing levels and transferring production to more productive wells. This is seen in three dimensions of restructuring: (i) restructuring of assets and projects, with acquisition of new assets and elimination of unprofitable projects; (ii) change in the capital structure, increasing or reducing debt and altering the risk; and (iii) changes in the dividend policy, since a decrease or increase in dividends leads to a decrease or increase in the retention ratio and expected growth rate (Damodaram, 1999).

**Methodology**

This article evaluates the possible impacts of the change from the concession model to the new framework for the pre-salt hydrocarbon reserves on the market value of Petrobras shares. The hypothesis is that the value of these shares fell or recovered at a slower pace in relation to the pre-salt period. According to Fraletti and Famá (2003), the pattern can be explained by the uncertainties generated due to the greater operational and market risks.

To test this hypothesis, we used a multiple regression model between the relative price of the common and preferred shares of the mining company Vale and those of Petrobras as the dependent variable and the ratio between the values of the two companies’ main products (iron ore and petroleum), proxied by the Commodity Metals Price Index\(^3\) and Commodity Fuel (energy) Index,\(^4\) and the proven oil reserves\(^5\) as the explanatory variables. The stock price data are the closing values of the common shares (VALE3
and PETR3) and preferred shares (VALE5 and PETR4). The levels of two commodity indexes were collected with monthly frequency between 2000 and 2014.

We chose Vale for comparison because it is a Brazilian company similar in size to Petrobras and also a large-scale producer of commodities sold on the domestic and foreign markets. This allows controlling for the effect of market risk inherent to the two companies, since both feel the impacts of changes in the Brazilian market. Therefore, we only observe the market risk inherent to Petrobras, which, as described, is due to the changes brought by the discovery of new pre-salt hydrocarbon fields (and characterized as an external risk) and the variation of the proven reserves of Petrobras, which include oil equivalent, natural gas liquids, and condensate as a source of power and exploitation.

It must be pointed out that there was no spot market price for iron ore in the period studied, so we adopted the Commodity Metal Index as a proxy. The behavior of important commodities, such as petroleum and iron ore, also affects the stock price behavior of the companies that produce these as their major products (Tilton, Humphreys, & Radetzki, 2011). The same must occur with the proven reserves of Petrobras. Therefore, by comparing the variations of the stock prices of these two companies and the relationship with commodities, controlling by proven reserves, it is possible to check for the existence of a structural change in the behavior of Petrobras shares.

To check for this structural change in the price of Petrobras stock after the change in the legal framework, we used two tests: the Bai and Perron (2003) test for multiple periods of structural change and the Chow (1960) test to confirm the previous result singly.

The model to apply the test of structural stability is based on the relative prices of the common shares of Vale and Petrobras (VALE3/PETR3), represented by $\text{RP}_{33}$, and their preferred shares (VALE5/PETR4), represented by $\text{RP}_{54}$, the relative values of the two commodity price indexes (metal index/fuel energy index), represented by $\text{RCOM}$, and the proven reserves of Petrobras, represented by $\text{RESERVES}$:

$$\text{RP}_{it} = \alpha + \beta_1 R\text{COM}_t + \beta_2 \text{RESERVES}_t + \epsilon_t$$

where:

$\text{RP}_{it}$ = relative price of the common share (i = 33) or preferred shares (i = 54) of Vale and Petrobras in period t; $\text{R}\text{COM}_t$ = relative price of the two commodity price indexes in period t; $\text{RESERVES}_t$ = Log of proven natural reserves of Petrobras in period t; $\alpha =$ linear coefficient; $\epsilon_t$ = i.i.d. $\sim$Normal (0, $\sigma^2$).

According to Chow (1960), linear regression models have been widely applied to measure relations in the fields of economics, dividend policies, stock prices, and cost and supply functions. In addition, it is possible to statistically test for structural changes in assets behavior by comparing two sets of observations belonging to the same regression model and by supposing
points where there were supposedly breaks or changes, as follows:

\[ y_{1i} = \beta_{10} + \beta_{11}X_{1i} + \beta_{12}X_{2i} + \ldots + \beta_{1(k-1)}X_{(k-1)i} + \varepsilon_{1i}; \ i = 1, 2, \ldots, n_1 \]  
(2)

\[ y_{2i} = \beta_{20} + \beta_{21}X_{1i} + \beta_{22}X_{2i} + \ldots + \beta_{2(k-1)}X_{(k-1)i} + \varepsilon_{2i}; \ i = n_1 + 1, n_1 + 2, \ldots, n \]  
(3)

The null hypothesis of Chow tests whether the coefficients \( (\beta_n) \) of models (2) and (3) are equal by identifying the respective sums of squares \( (S_{(2)} \) and \( S_{(3)} \)) through the following statistic:

\[ F = \frac{RSS_T}{(RSS_T)/(T - 2K)} \]  
(4)

where:

\( RSS_T = \) Residual Sum Square Total or \( RSS_{(2)} + RSS_{(3)}; \ K = \) number of parameters; \( T = \) number of years in the sample size.

However, most tests, including the Chow test, assume only one structural change in a given period. Bai and Perron (1998) tested multiple structural changes in a linear regression model and later developed an algorithm based on dynamic programming for any number of structural breaks (Bai and Perron, 1998; 2003), as follows:

\[ y_t = \beta_1X_{t-1} + \varepsilon_t; \ t = 1, 2, \ldots, T \]  
(5)

\[ y_t = \beta_{q+1}X_{t-1} + \varepsilon_t; \ t = T_q + 1, \ldots, T \]  
(6)

The number of breaks could be calculated in many ways. According to Bai and Perron (1998, 2003), if the number of breaks is known, the proposed method consists of estimating the first breakpoint. Then, the sample is divided into two and the structural break model is estimated for each of them to generate new break points. The goal is to reduce the sum of squared residuals, as much as possible, repeating the process until all structural breaks are found. On the other hand, if this number is unknown, the null-hypothesis of \( n \) structural breaks is tested against the alternative hypothesis of “\( n + 1 \)” breaks. Finally, the number of breaks can be selected by using penalized likelihood methods, such as the Schwarz information criterion or Akaike’s information criterion, which differ in terms of the penalty they apply to the inclusion of additional breakpoint parameters.

**Analysis of the results**

The results of the two analyses conducted in this study confirm the hypothesis that the Petrobras stock price fell, or recovered at a slower pace, related to the pre-salt period of exploitation and production activities based on structural breakpoints are. The main goal was to identify whether a structural change occurred in the stock price behavior around August 2008, when the pre-salt
process began. This analysis was based on the ratio between the common and preferred shares of Vale and those of Petrobras, the ratio between the prices of the commodities produced by these companies, and the proven oil reserves of Petrobras.

The results of regression model follow as:

\[
RP_{33} = -11.82 - 0.16 RCOM + 1.88 RESERVAS \\
    \text{(0.000)} \quad \text{(0.144)} \quad \text{(0.000)}
\]

\[F_{\text{statistic}} = 121.9; \quad R^2_{\text{adj}} = 0.574\]

\[
RP_{54} = -10.05 - 0.08 RCOM + 1.620 RESERVAS \\
    \text{(0.000)} \quad \text{(0.396)} \quad \text{(0.000)}
\]

\[F_{\text{statistic}} = 112.64; \quad R^2_{\text{adj}} = 0.555\]

The values below the equation are the \(p\)-value, which indicates significance at 5%. We can observe that the ratio of commodity prices was not statistically significant and the structural breakpoint tests were conducted without this variable in the model.

The test proposed by Bai and Perron (2003) allows observing potential multiple structural breaks. The advantage is not having to impose a date for the structural break a priori for testing, considering that the dates can be variable and random.

In the case of Petrobras’ stock price, we did not establish the expected number of breaks. Instead, we tested the hypothesis of at least one structural change, in 2008, the month after the four bills were sent to Congress to change the rules for pre-salt E&P activities. Tables 1 and 2 show the results of the Bai-Perron tests of \(L+1\) vs. \(L\) sequentially determined breaks.

**Table 1.** Bai-Perron breakpoint test of the equation: \(RP_{33} = \alpha + \beta_1 RCOM_t + \beta_2 RESERVES_t + \epsilon_t\).

<table>
<thead>
<tr>
<th>Break Test</th>
<th>Sequential F-statistic</th>
<th>Scaled F-statistic</th>
<th>Critical Value**</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 vs. 1*</td>
<td>7.504.387</td>
<td>1.500.877</td>
<td>11.47</td>
</tr>
<tr>
<td>1 vs. 2*</td>
<td>3.108.081</td>
<td>6.216.162</td>
<td>12.95</td>
</tr>
<tr>
<td>2 vs. 3*</td>
<td>1.260.908</td>
<td>2.521.817</td>
<td>14.03</td>
</tr>
<tr>
<td>3 vs. 4</td>
<td>1.091.437</td>
<td>2.182.874</td>
<td>14.85</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Break dates:</th>
<th>Sequential F-statistic</th>
<th>Repartition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2010M10</td>
<td>2002M07</td>
</tr>
<tr>
<td>2</td>
<td>2002M06</td>
<td>2008M05</td>
</tr>
<tr>
<td>3</td>
<td>2008M05</td>
<td>2010M10</td>
</tr>
</tbody>
</table>

*Significant at the 0.05 level.

**Bai-Perron (Econometric Journal, 2003) critical values.

Source: Authors’ analysis by Eviews.
and Perron (2003) test and the number of structural breaks found, with the respective dates.

In both models of the common shares ($RP_{33}$) and preferred shares ($RP_{54}$), three breakpoints were found: July 2002, May 2008, and October 2010.

Since the break dates were already found and to reinforce the results, we applied the Chow (1960) test by analyzing one by one breakages, as seen in Tables 3 and 4.

Tables 3 and 4 present the $p$-values of the Chow test for each breakpoint. It can be seen that in July 2002, May 2008, and October 2010 the null hypothesis

**Table 2.** Bai-Perron breakpoint test of the equation: $RP_{54} = \alpha + \beta_1 RCOM_t + \beta_2 RESERVES_t + \epsilon_t$.

Bai-Perron tests of L+1 vs. L sequentially determined breaks
Date: 02/26/16 Time: 16:21
Sample: 2000M01 2014M12
Included observations: 180
Breakpoint variables: C LOG(RESERVA)

<table>
<thead>
<tr>
<th>Sequential F-statistic determined breaks:</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Break Test</td>
<td>$F$-statistic</td>
</tr>
<tr>
<td>0 vs. 1*</td>
<td>7.131.341</td>
</tr>
<tr>
<td>1 vs. 2*</td>
<td>3.703.017</td>
</tr>
<tr>
<td>2 vs. 3*</td>
<td>9.898.074</td>
</tr>
<tr>
<td>3 vs. 4</td>
<td>1.504.534</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Break dates: Sequential</th>
<th>Repartition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2010M10</td>
</tr>
<tr>
<td>2</td>
<td>2002M06</td>
</tr>
<tr>
<td>3</td>
<td>2008M05</td>
</tr>
</tbody>
</table>

*Significant at the 0.05 level.
**Bai-Perron (Econometric Journal, 2003) critical values.
Source: Authors' analysis by Eviews.

**Table 3.** Chow test of stability for 2002, 2008, and 2010. Equation: $RP_{33} = \alpha + \beta_1 RCOM_t + \beta_2 RESERVES_t + \epsilon_t$.

Null Hypothesis: No breaks at specified breakpoints
Varying regressors: All equation variables
Equation Sample: 2000M01 2014M12

<table>
<thead>
<tr>
<th>Chow Breakpoint Test: 2002M07</th>
<th>F-statistic</th>
<th>Prob. $F(2,176)$</th>
<th>0.0410</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chow Breakpoint Test: 2008M05</td>
<td>F-statistic</td>
<td>Prob. $F(2,176)$</td>
<td>0.0001</td>
</tr>
<tr>
<td>Chow Breakpoint Test: 2010M10</td>
<td>F-statistic</td>
<td>Prob. $F(2,176)$</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

Source: Authors' analysis by Eviews.
Note: Significance level of 5%.
of stability started to be rejected at 5% significance in both regression of the common shares (RP33) and preferred shares (RP54). Thus, we can confirm one by one break dates by this test.

Therefore, as expected, a structural break occurred in May 2008 for the common (RP33) and preferred shares (RP54), indicated by both models, before the four bills were sent to Congress (August 31, 2008). Thus, the market anticipated the changes in the rules on pre-salt reserves and the greater government participation in Petrobras. The structural break also occurred in October 2010, which could be related to the issuance of shares to raise funds for the pre-salt.

The objective of this article is not to study possible structural breaks at moments other than those subject to the change in the regulation of oil exploration and production in Brazil with the discovery of the pre-salt reserves. Therefore, we did not analyze the structural breaks in 2002, which can be associated, for example, with the election of President Lula, who was an opponent at that time.

In Figures 1 and 2, this finding can be observed more strongly for Petr3 and Vale3, because in May 2008 and in October 2010 the two series started to fall, a pattern that is more evident in 2010. These graphs do not show the result of the model, because they do not consider the relative commodity prices or proven reserves; thus, they serve only as illustration and intuition of the proposition.

**Final considerations**

The objective of this study was to investigate the effect of the changes in the rules applicable to the pre-salt reserves, including the shift from the

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**Table 4.** Chow test of stability for 2002, 2008, and 2010. Equation: $RP54 = \alpha + \beta_{1i}RCOM_t + \beta_{2i}RESERVES_t + \epsilon_{it}$.

Null Hypothesis: No breaks at specified breakpoints

<table>
<thead>
<tr>
<th>Varying regressors: All equation variables</th>
<th>Equation Sample: 2000M01 2014M12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chow Breakpoint Test: 2002M07</td>
<td></td>
</tr>
<tr>
<td>F-statistic</td>
<td>3.6235</td>
</tr>
<tr>
<td>Prob. $F(2,176)$</td>
<td>0.0287</td>
</tr>
<tr>
<td>Log likelihood ratio</td>
<td>7.2632</td>
</tr>
<tr>
<td>Prob. Chi-Square(2)</td>
<td>0.0265</td>
</tr>
<tr>
<td>Wald Statistic</td>
<td>7.2470</td>
</tr>
<tr>
<td>Prob. Chi-Square(2)</td>
<td>0.0267</td>
</tr>
<tr>
<td>Chow Breakpoint Test: 2008M05</td>
<td></td>
</tr>
<tr>
<td>F-statistic</td>
<td>5.8582</td>
</tr>
<tr>
<td>Prob. $F(2,176)$</td>
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</tr>
<tr>
<td>Log likelihood ratio</td>
<td>11.6008</td>
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<tr>
<td>Prob. Chi-Square(2)</td>
<td>0.0030</td>
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<tr>
<td>Wald Statistic</td>
<td>11.7165</td>
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<tr>
<td>Prob. Chi-Square(2)</td>
<td>0.0029</td>
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<tr>
<td>Chow Breakpoint Test: 2010M10</td>
<td></td>
</tr>
<tr>
<td>F-statistic</td>
<td>71.3134</td>
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<tr>
<td>Prob. $F(2,176)$</td>
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<tr>
<td>Log likelihood ratio</td>
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<tr>
<td>Prob. Chi-Square(2)</td>
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<tr>
<td>Wald Statistic</td>
<td>142.6268</td>
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<td>Prob. Chi-Square(2)</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

Source: Authors’ analysis by Eviews.

Note: Significance level of 5%.
concession model to the production sharing regime, on the stock price of Petrobras. The negative effect on the company’s value is based on the hypothesis that the slower recovery of the stock price in relation to other companies (Vale being the proxy for comparison) after the 2008 crisis was the result of market risk and operational risk generated by the insecurity of investors and other market participants. The operational and market risks are related to the need for capitalization to acquire resources and technology (which might not be sufficient) for exploration in deep waters; the changes in legislation, requiring the company to participate in all the consortiums formed to explore and

**Figure 1.** Petrobras and Vale common shares price performance.

**Figure 2.** Petrobras and Vale preferred shares price performance.
exploit hydrocarbon reserves in the pre-salt formations; the increase in the governments equity stake, enabling heightened intervention; and uncertainty about the quantity and quality and extraction cost of the oil to be found.

To ascertain any change in the behavior of the price of Petrobras stock in 2008, when four bills were sent to Congress proposing important changes in the rules, and 2010, when shares were issued for a new capitalization of around R $115 billion, we conducted two analyses. These were based on the ratio between the stock prices of Vale and Petrobras, the ratio between the two main commodities produced by these companies and the proven reserves of Petrobras. Bai and Perron (2003) test, confirmed by Chow (1960) test, identified structural breaks in the Petrobras stock price series in the period of the shift in rules, more specifically in 2008 and 2010. This provides evidence that the market risks under the new legal framework, the operational risks due to the capitalization to acquire equipment and technology, and the influence of the government—the main stakeholder might have influenced the company’s stock price, causing it to recover more slowly than other companies after the 2008 crisis. These results corroborate findings in the studies of Borisov and colleagues (2015), Dinç (2005), Faccio (2006), Firth and associates (2013), Lazzarini and Musacchio (2010), Sapienza (2004), and Thomsen and Pedersen (2000).

Nevertheless, some additional questions for future research are as follows. What are the risks of having the government as the main shareholder (48% of the total capital and the majority of the voting shares) of the company that must participate in all the consortiums formed for exploration of the pre-salt reservoirs and also another state-owned company in charge of managing the fields and choosing the companies that will process the oil? What will be the consequences of investing in the absence of certainty about the quality and quality of the oil to be found? And what will be the consequence of the high investment in technology for exploration and extraction in deep water on the price of oil?

Notes

1. Some petroleum industry sources distinguish among post-salt, pre-salt, and subsalt reserves: “Post-salt refers to crude oil and natural gas reservoirs lying above and deposited after an autochthonous (deposited in its present position) salt layer. Pre-salt refers to reservoirs lying beneath and deposited prior to an autochthonous salt layer. Subsalt refers to reservoirs lying beneath allochthonous (deposited at a distance from its present position) salt layers” (Chevron Glossary of Energy and Financial Terms, 2013). Others use subsalt alone to describe the formations in Brazil: “Vast subsalt oil reserves have been uncovered in Brazil, the Gulf of Mexico and west Africa, but extreme pressure and inhospitable conditions have made extraction a challenge” (“Big oil sinks to the depths,” in The New Economy, October 3, 2012). Finally, some use subsalt and pre-salt synonymously, for example, “Brazil’s state-controlled oil producer Petrobras has reported a subsalt oil
discovery in the fourth well drilled in the Jupiter area in the Santos Basin pre-salt block BM-S-24” (Offshore Technology.com, August 14, 2014). In deference to Brazilian usage (pré-sal in Portuguese), we use “pre-salt” in this article.

2. The FGTS is the “Guarantee Fund for Time of Service,” a severance indemnity fund into which employers must deposit 8% of each employee’s salary every month, in an individual blocked savings account held by each worker at Caixa Econômica Federal, a state-owned bank. The balance in the account is released on retirement or being laid off.


References


