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State-controlled companies and political risk: Evidence from the 2014 Brazilian election☆

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ABSTRACT

The 2014 Brazilian election offers an opportunity to estimate the vulnerability of state-controlled companies to political risk. This paper proposes a method for studying the effect of an election on asset prices using only data on stock options. We apply this method to the 2014 Brazilian Presidential election. Results suggest that Petrobras, the Brazilian oil company, would be worth around 60%–65% more if the incumbent, Ms. Rousseff, had not been reelected. We also find that reelection had a negative impact on the stock market index, but state-controlled companies were more strongly affected.

1. Introduction

How vulnerable to political risk are state-controlled companies in emerging economies? Petrobras, the Brazilian oil company, is a particularly interesting case. It is controlled by the Brazilian government, but most of its non-voting shares and a sizable part of voting shares are publicly traded. Once the largest company in Latin America, it has seen its value decline by > 90% (in Dollars) between the end of 2010 and the end of 2015. Part of this decline might be due to political factors. During her first term as president (between 2011 and 2014), Ms. Dilma Rousseff took several measures that were not aligned with the objective of maximizing Petrobras' profits.

The 2014 Brazilian election offers us an opportunity to assess the impact of a change in government via elections on the value of Petrobras for its shareholders. The main contenders in the election were Ms. Rousseff and Mr. Neves, an opposition candidate identified with a pro-market platform. In a hotly contested race, Ms. Rousseff was re-elected by a narrow margin. If national politics is an important source of risk for Petrobras, an opposition victory should be associated with a large increase in the price of its shares.

A recent literature studies the effect of elections on asset prices using data on probabilities of each outcome from prediction markets.[1] However, in Brazil, as in many other countries, there is no such data.[2]

This paper proposes a method to study the effect of an election on asset prices using data on stock options. We extend a standard asset pricing model, the Heston (1993) diffusion model, by including (i) the gap in valuation of the asset conditional on the election winner; and (ii) a time series of daily outcome probabilities that reflect changing market expectations for the election.

Estimating the model with option data yields estimates for the gap in valuation; the probability of each election outcome at each date; and disturbances unrelated to the election. Intuitively, these variables affect the probability distribution of the underlying asset in different ways. Options with different strike prices carry information about different moments of the probability distribution of the asset, hence they allow us to identify the parameters of the model.

We estimate the value of Petrobras shares conditional on different election outcomes of the 2014 Brazilian presidential election. Using

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[1] For example, Herron et al. (1999) and Knight (2006) use data from the Iowa Electronic Markets on the probability of each outcome in US presidential elections, Snowberg et al. (2007) use the market-based probability of a Bush reelection in 2004 from Tradesports, Wolfers and Zitzewitz (2009) use the so-called Saddam securities from Tradesports and Imai and Shelton (2011) use data from a political prediction market in Taiwan.

[2] Ferraz (2015) built and studied a prediction market for Brazilian elections. However, market participants used play money and there were clear arbitrage opportunities – for instance, selling all contracts the day before the election, implying a certain liability of $100, would yield $111.7.

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data on Petrobras options traded in the Sao Paulo exchange, we find that Petrobras preference shares would have cost 65%–70% more (in Reais) had the opposition candidate been elected. In order to assess the effect of the election on the value of the company, we also need to estimate the effect of the election on the price of ordinary shares of Petrobras. These were less responsive to movements in the odds of re-election. A back of the envelope calculation suggests that Petrobras would be worth 61%–65% more if Ms. Rousseff had lost the election. This effect is huge both in relative and absolute terms, as it translates into a difference in company valuation around USD 45 billion.

The results for the probabilities of each election outcome are in general agreement with the movements in presidential polls. Reassuringly, from the election day on, the estimates attribute probability very close to 1 to a win by the elected president.

We then repeat the exercise using Petrobras options traded in the New York Stock Exchange. We find that ordinary Petrobras shares would have cost around 80% more (in Dollars) in the case of an opposition victory. This is roughly what one would expect considering the different underlying assets (preference and ordinary shares) and different currency denominations (Reais and Dollars). Estimates for the probability of reelection are also similar to those obtained using data on options traded in Sao Paulo.

Using options on the Brazilian stock market index (Ibovespa), we estimate that an opposition victory in the election would have raised the stock market index by 18%. We also use our estimated probabilities of reelection to assess the effect of political risk on a variety of asset prices. We find that the election of Ms. Rousseff had a strong negative effect on the value of many companies. However, the effects on Petrobras, Banco do Brasil (a state-controlled bank) and Eletrobras (a state-controlled electricity company) were particularly strong. Taken as a whole, the results provide supporting evidence that state-controlled companies are particularly vulnerable to political risk and highlight how large this risk can be.

The remainder of this introduction discusses the relation between this paper and the literature. Section 2 describes policies adopted by President Rousseff that affected the value of Petrobras during her first term in power and provides information about the 2014 Brazilian election. Section 3 explains the empirical model. Section 4 describes the data and estimation and discusses the intuition for identification. Section 5 presents and discusses the results and Section 6 concludes.

1.1. Related l iterature

This paper is related to a literature that studies the effects of elections on asset prices to gauge how different parties affect the economy. Herron (2000) finds that higher interest rates and lower stock market prices were expected had the Labour Party won the British elections in 1992; Knight (2006) studies how the odds of a victory for Bush or Gore in the 2000 American election affected the market value of politically sensitive firms and finds that policy platforms were capitalized into equity prices; Imai and Shelton (2011) show that share prices of Taiwanese firms with investments in the mainland responded strongly to a positive electoral outlook for the party that advocates lifting caps on cross-strait investment in mainland China; and Snowberg et al. (2007) study how the Bush reelection in 2004 affected stock markets and find that electing a Republican President raises equity valuations by 2–3%.[3] Closely related to this literature, Wolfers and Zitzewitz (2009) estimate the effect of the Iraq War on oil prices and on the U.S. stock market.

This paper is also related to a literature that connects political risk, market volatility and uncertainty premia. Pantzalis et al. (2000) find positive abnormal returns in the weeks leading to an election in their sample of 33 countries. Brogaard and Detzel (2015), employing the uncertainty measure of Baker et al. (2016), also find that economic policy uncertainty is associated with positive abnormal returns. Using options, Kelly et al. (2016) assess the effect of political risk on asset prices studying events like summits and elections. They show that options whose lives span political events are on average 5% more expensive than otherwise similar options. Goodell and Vähämaa (2013) also find a link between stock market volatility and political uncertainty using the VIX volatility index and data from the Iowa Electronic Markets over five US presidential elections.

A growing empirical literature examines how political connections affects firms. Fisman (2001) estimates the value of political connections in Indonesia by assessing the effect of news about President Suharto's health on firms with differing degrees of political exposure; Johnson and Mitton (2003) argue that Malaysian capital controls provided a screen behind which favored firms could be supported; Khwaja and Mian (2005) argue that politically connected firms in Pakistan default on loans that are taken with the intention of not being returned; Leuz and Oberholzer-Gee (2006) argue that foreign securities and close political connections are substitutes; Faccio (2006) uses data from many firms in 47 countries and finds significant abnormal returns for establishing political connections; Faccio et al. (2006) show evidence that politically connected firms are more likely to be bailed out; Ferguson and Voth (2008) assess the value of political connections in Nazi Germany; Acemoglu et al. (2018) show that street protests in Egypt are associated with lower stock market value for firms connected to the group in power.

Previous work has explored the link between finance and politics in Brazil. Claessens et al. (2008) show that political connections affect access to bank finance in Brazil, which in turn affects stock returns. Carvalho (2014) presents evidence that BNDES, the Brazilian development bank, expands (subsidized) loans in politically attractive regions right before elections. Fernandes and Novaes (2016) study the role of the Brazilian government as a large shareholder in recent years. They show that government activism lowered the value of minority shareholders' voting rights, which harmed minority shareholders in Brazil.

A sizable empirical literature shows that state owned firms are usually less profitable than private companies.[4] Hence, all else equal, state controlled firms are worth less than private companies. By showing that Petrobras is subject to very large political risk, this paper points out that this difference can be strongly affected by the incumbent government – at least in emerging economies, where institutions are strong enough to allow for the existence of capital markets, but may fail to prevent policies that negatively affect the value of a state-controlled company for its shareholders.

A sizable literature has emphasized the effect of slow-moving institutional and legal factors on the rights of minority shareholders.[5] This paper asks whether changes through elections can also have a large impact on the value of a state-controlled company.[6]

One distinguishing feature of our paper is the use of stock options to estimate both the probability of each outcome and their effects on the value of the company. Data on options have been used to extract

[3] There is also a literature on the relation between stock returns and the party in power (see, e.g., Santa-Clara and Valkanov, 2003; Leblang and Mukherjee, 2005).

[4] For example, Boardman and Vining (1989) and Dewenter and Malatesta (2001) compare the largest private-owned and government-owned firms and find the former are, on average, significantly more profitable. La Porta and Lopez-de Silanes (1999) use data from privatized firms in Mexico and find that productivity gains are the main drivers of the increased in profits from privatization. Sapienza (2004) finds that in Italy, all else equal, state-owned banks charge lower interest rates than do privately owned banks and attributes this difference to political distortions. Using data on Indian state-owned companies, Gupta (2005) finds that partial privatization has a positive impact on profitability, productivity, and investment. An exception in this literature, highlighting the value of political connections, is Calomiris et al. (2010). They argue that in China, the benefits of political ties outweigh the efficiency costs of government shareholdings. For a survey of the empirical literature on privatization, see Megginson and Netter (2001).

[5] See La Porta et al. (2000, 2002) and a literature that followed.

[6] There is a related discussion in development economics about the relative roles of institutions and macroeconomic policies (see, e.g., Henry and Miller, 2009).

information about the probability distribution of assets in a variety of ways. One branch of this literature builds on Breeden and Litzenberger (1978) to estimate probability densities of assets. Variations of this method have been used to back out the probability distribution of assets in foreign exchange markets (e.g., Campa and Chang, 1996; Campa et al., 2002), bond markets (e.g., Söderlind and Svensson, 1997) and stock markets (e.g., Aït-Sahalia and Lo, 1998).

This paper is closer to the branch of this literature that employs extensions of the models of Black and Scholes (1973), Merton (1976), Hull and White (1987) and Heston (1993) to back out parameters that characterize the probability distribution of an asset. This methodology has been applied to study whether a stock market crash was somewhat expected (Bates, 1991), to estimate realignment probabilities of European exchange rates (Malz, 1996; Bates, 1996), to understand pricing of foreign currency options (Melino and Turnbull, 1990), to infer expectations about equity markets (Bakshi et al., 1997; Bates, 2000), among other things.

This paper is particularly related to work that uses options to study the impact of scheduled events on asset prices. Beber and Brandt (2006) show that macroeconomic announcements reduce the implied volatility of US Treasury bond future prices. Patell and Wolfson (1979) study the effects of earnings announcements by investigating how the implied Black-Scholes volatility behaves around announcement dates. Closer to our methodology, Dubinsky and Johannes (2006) use a simple diffusion model and data on options to disentangle the uncertainty over the information revealed on earnings dates from normal day-to-day volatility. Our empirical model is different, more suitable to a binary event like an election.

Few papers use options to study the effect of elections. Besides Kelly et al. (2016) and Goodell and Vähämaa (2013), Gemmill (1992) studies the 1987 British election and finds evidence of inefficiency in the option market. Leahy and Thomas (1996) investigate how a referendum in Canada affected expectations about the exchange rate using the method developed by Melick and Thomas (1997), which posits that the asset price is described by a mixture of log-normal distributions. Related to this literature, Wolfers and Zitzewitz (2009) employs the non-parametric method of Aït-Sahalia and Lo (1998) to back out the probability distribution of the S&P 500 index and then study how they were affected by the odds of a war on Iraq.

2. Background

2.1. Petrobras under the government of Ms. Rousseff

President Dilma Rousseff and Petrobras have grabbed newspaper headlines in the whole world for what has been considered the biggest corruption scandal in Brazilian history, the so called “Big Oily”. From the point of view of minority shareholders, the key implication of this corruption scheme is that a lot of money was diverted from the company.[7]

Corruption is, however, only one among the several ways through which actions undertaken by the government of Ms. Rousseff were detrimental to Petrobras' minority shareholders. In fact, much of the problem stems from conflicting interests between the main shareholder, the government, and minority shareholders.

The ‘Local content act’ required that equipment bought by Petrobras had to contain a certain amount of nationally produced components.[8] The local-content constraint was clearly binding. This protectionist measure was justified as part of an effort to foster industrialization in Brazil. Whatever one thinks of this kind of development policy, the fact is that Petrobras was footing the bill.

In another example of government action costly to Petrobras, the increase in oil prices for consumers was substantially below inflation during Ms. Rousseff's first term. In Brazil, a substantial share of prices is controlled by the government. During that period, inflation had overshot the target and the government attempted to reduce the official rate by keeping controlled prices down. Again, this policy was detrimental to the profitability of Petrobras.

Petrobras' shares are widely dispersed across minority shareholders. Owing to one particular feature of Brazilian labour regulations, even those who do not regularly participate in the stock market might own Petrobras shares. Part of the payments from employers to employees (around 8% of the wage) is deposited into an account that an employee can only access when she is fired, retires, or under some special conditions (e.g., buying a house). Over the past decade, this account has been remunerated at negative real interest rates.[9] On a few occasions, the government has allowed people to use resources from this account to buy Petrobras shares. Hence the set of minority shareholders of Petrobras is very large and heterogeneous, including all groups except the very poor, who do not work in the formal sector.

2.2. The election

The presidential election in Brazil is held in two rounds. If no candidate achieves 50% of the votes in the first ballot, there is a second ballot three weeks later involving only the two front runners from the first round.

A casual look at the data suggests a negative association between the odds of reelection of Ms. Rousseff and the price of a share of Petrobras. The top panel of Fig. 1 shows the price of a Petrobras share in this period (in Brazilian Reais). Note how large price fluctuations are. The bottom panel of Fig. 1 shows data from opinion polls regarding the difference in vote intentions in a second ballot between Ms. Rousseff and the candidate that, at each point in time, seemed more likely to beat her (a positive difference means Ms. Rousseff was ahead). The correlation is clearly negative.

Before August 13, opinion polls had Ms. Dilma Rousseff from the Worker's Party (PT) in first place, with Mr. Aecio Neves from the Brazilian Social-Democratic Party (PSDB) in second and Mr. Eduardo Campos from the Brazilian Socialist Party (PSB) in third with a little under 10% of vote intentions. In a predicted second ballot between Ms. Rousseff and Mr. Neves, the former was ahead. In the midst of the political campaign, on August 13, Mr. Campos died in a plane crash. His running mate Ms. Marina Silva stepped up to take his place as presidential candidate.

The first vertical line marks the date of the plane crash. In only three weeks, the price of Petrobras shares went up by a whopping 30%. As the bottom graph shows, these three weeks witnessed a large drop in vote intentions for Ms. Rousseff. By early September, opinion polls showed a tie between Ms. Silva and Ms. Rousseff in the first ballot and a 10-percentage-point lead by Ms. Silva in a projected second round. Mr. Neves was then far behind in third place. However, the campaign for Ms. Rousseff in September was very successful and by the end of the month, opinion polls showed Ms. Rousseff clearly ahead of the opposition candidates and with a chance to clear the 50% bar in the first ballot. In turn, the price of Petrobras shares plummeted from around BRL 24 to close to BRL 17 in the month of September. Opinion polls had Mr. Neves trailing Ms. Silva until a couple of days before the first ballot.

The first ballot, marked by the second vertical line in Fig. 1, was held on Sunday October 5 and was much closer than expected, with the incumbent Ms. Dilma Rousseff beating Mr. Aecio Neves by only 8 percentage points (41.59% to 33.55%). This coincided with the largest overnight price increase in Petrobras shares. Ms. Marina Silva came in

[7] See, e.g., *The Economist*, January 3rd, 2015, “The big oily”. The report notes that “minority shareholders are furious”.

[8] Law 12,351 from December 22, 2010.

[9] For example, in 2015, nominal interest rates on this account were below 5%, while inflation was above 10% and interest rates on government bonds were around 14%.

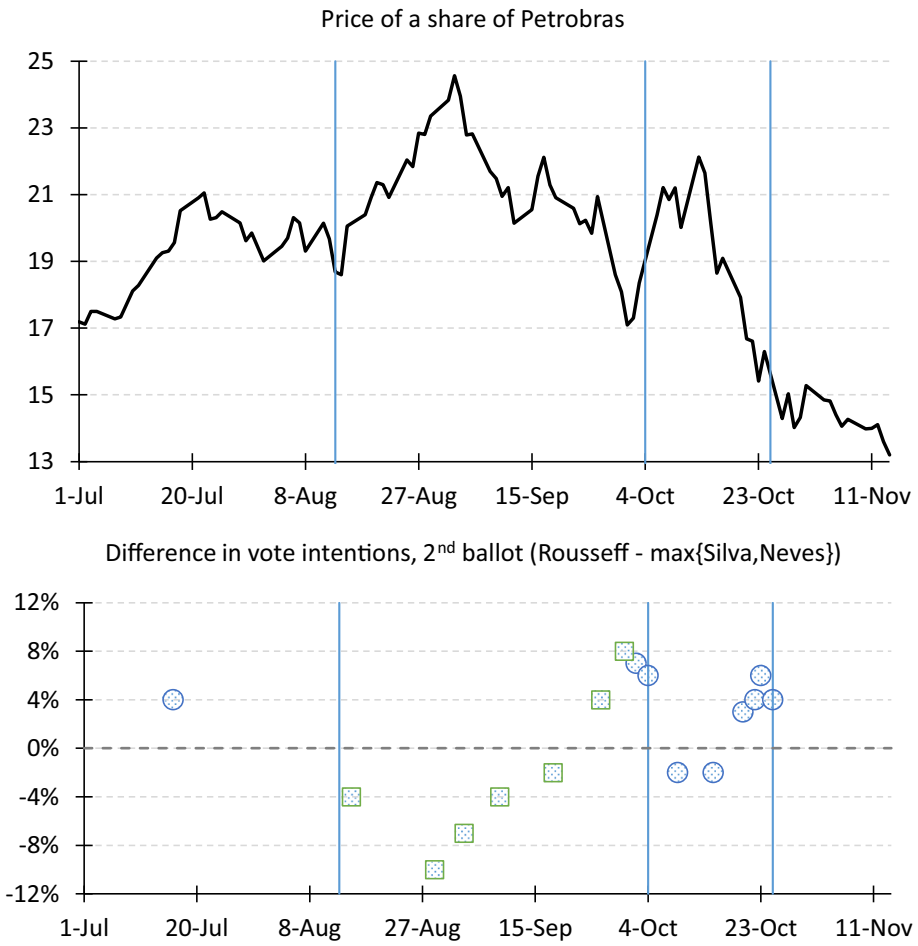

Fig. 1. Top panel: price of Petrobras shares. Bottom panel: Difference in vote intentions in the second ballot between Ms. Rousseff and Mr. Neves (circles) and between Ms. Rousseff and Ms. Silva (squares) according to opinion polls. Vertical lines mark the dates of the death of Mr. Campos, the first ballot and the second ballot, from left to right.

third place, with 21.32% of the votes. The remaining 8 candidates had < 5% of the votes.

The second ballot between Ms. Rousseff and Mr. Neves, marked by the third vertical line in Fig. 1, was one of the closest presidential elections in Brazilian history. In the first two weeks after the first ballot, opinion polls showed no statistically-significant advantage for either candidate. The fierceness of the race was reflected by the overall tense political climate of the country. On Sunday October 26, the drama came to a close with Ms. Rousseff being reelected president of Brazil, beating Mr. Neves 51.64% to 48.36%. The outcome was known on the same day at 8 pm.

On Monday after the second ballot, with the reelection of Ms. Rousseff confirmed, Petrobras shares went down by 12%. Since at that point Ms. Rousseff was the favorite to win, the key question is what would have happened to the price of Petrobras had Mr. Neves won the election.

3. The empirical model

We augment an asset diffusion process by assuming there are two possible election outcomes, *High* and *Low*. Denote by $S_{high}(t)$ and $S_{low}(t)$ the asset value conditional on outcomes *High* and *Low*, respectively, and define Δ as the following:

$$\Delta \doteq \frac{S_{high}(t)}{S_{low}(t)}$$

In our estimation, Δ is assumed to be known and constant, reflecting the idea that market expectations about each candidate's effect on the value of Petrobras are not expected to change significantly in only 3 weeks.[10]

The asset value conditional on a low outcome follows a diffusion process. The event defining which outcome is chosen is the second round of the election, which will happen at time $\overline{T}$. For $t < \overline{T}$, the probability of outcome *Low* is given by $\theta(t)$, with $0 \leq \theta(t) \leq 1$ for all $t < \overline{T}$). For any $\tilde{t} > t$, we have that $\mathbb{E}_t[\theta(\tilde{t})] = \theta(t)$ (probabilities are martingale).

Shocks to $S_{low}(t)$ and θ are assumed to be uncorrelated. However, one could argue that positive shocks to the world economy or to oil prices could raise both $S_{low}(t)$ and the probability of reelection $\theta(t)$. As shown by Snowberg et al. (2007), this would bias our estimates and the size of the bias would depend on the correlation between shocks to the shadow price of Petrobras and shocks to the odds of reelection.

A positive correlation between shocks to $S_{low}(t)$ and $\theta(t)$ would lead to a downward bias in our estimator of Δ. Conditional on the reelection of Ms. Rousseff, $S_{low}(t)$ would be larger (in expected terms). Since the *Low* state corresponds to a victory by Ms. Rousseff, that would reduce the observed difference in the expected value of Petrobras in both states. Hence our estimate of Δ would be smaller than the actual valuation gap.

However, the correlation between shocks to $S_{low}(t)$ and $\theta(t)$ is arguably small. First, because there are very large fluctuations in vote intentions from opinion polls that seem unrelated to news about the

[10] This assumption is not essential for our results. See the working paper version of Carvalho and Guimaraes (2016).

domestic economy.[11] Second, because Brazil is a large and relatively closed economy,[12] so GDP and wages are not so strongly affected by shocks to the world economy (and to oil prices) that are important for Petrobras.

We also use the model to investigate the relation between Ms. Rousseff's reelection and the stock market index. In this case, the first reason for a low correlation between shocks to $S_{low}(t)$ and $\theta(t)$ applies, but the second does not. Hence the estimator of Δ for the stock market index is more likely to suffer from the downward bias discussed above.

As the bulk of the literature, this paper uses options to retrieve parameters of state price densities, that correspond to the real probability density functions only if options are priced by risk-neutral agents. However, in the case we study, this assumption seems not so strong. The daily trading volume of Petrobras American Depositary Receipts in the New York Stock Exchange far exceeds the trading volume of Petrobras shares in the Sao Paulo Stock Exchange.[13] Prices of Brazilian shares and American Depositary Receipts of Petrobras at a given moment are virtually identical. Under the plausible assumption that Brazilian-specific election risk is diversifiable (or close to diversifiable) for foreign investors, risk considerations would not have a large effect on option prices.

Under the risk-neutrality assumption, the observed stock price $S^*(t)$ is given by

$$S^*(t) = \theta(t)S_{low}(t) + (1 - \theta(t))S_{high}(t) \tag{1}$$

Denote by $\widetilde{C}(S)$ the price of a call option for an asset with spot price S that follows the assumed diffusion process (given the strike price, the time to maturity and the interest rate). As shown in Appendix A, the price of a call in this model $C(S_t^*)$ is given by

$$C(S_t^*) = \theta(t)\widetilde{C}(S_{low}(t)) + (1 - \theta(t))\widetilde{C}(S_{high}(t)) \tag{2}$$

Combining Eqs. (1) and (2), we get an expression for the price of a call that depends only on the observed stock price $S^*(t)$ and parameters of the model:

$$C(S_t^*) = \theta(t)\widetilde{C}\left(\frac{S_t^*}{\theta(t) + (1 - \theta(t))\Delta}\right) + (1 - \theta(t))\widetilde{C}\left(\frac{S_t^*\Delta}{\theta(t) + (1 - \theta(t))\Delta}\right) \tag{3}$$

The formula for $\widetilde{C}$ depends on the diffusion process considered. The expression for the price of a European put is analogous.

3.1. The diffusion model

In principle, this method can be coupled with any diffusion model, but which one is more suitable to our purposes? The Black and Scholes model, for its simplicity, looks like a natural first choice. However, while the Black and Scholes model implies a log-normal probability distribution for the value of the underlying asset, there is robust evidence that probability distributions of asset values have thicker tails. The problem is that an extension of the Black and Scholes model with $\Delta > 1$ and $\theta \in (0,1)$ could help to fit the data even in the absence of a binary event like an election.[14] Intuitively, the tails of the probability distribution of the underlying asset implied by the model would be thinner than in reality, hence prices of out-of-the-money options would be smaller than they should be. This would be (imperfectly) compensated by a larger Δ, which leads to larger prices of out-of-the-money options.

It is thus important to employ a diffusion model that generates a leptokurtic distribution for S_{low} consistent with the data in no-election times. Most diffusion models that satisfy this criterion have either jumps or stochastic volatility (or both). Since our parameters of interest are the size and the odds of a jump, a diffusion model with stochastic volatility seems more appropriate. Among models with stochastic volatility, the Heston model was selected for its (relative) analytical convenience.

In the model of Heston (1993), the diffusion process is given by

$$\frac{dS_{low}(t)}{S_{low}(t)} = \mu dt + \sqrt{v(t)}\,dW_{1t}.$$

Volatility itself is assumed to follow a diffusion process:

$$dv(t) = \kappa(\alpha - v(t))dt + \xi\sqrt{v(t)}\,dW_{2t},$$

where κ, α and ξ are positive parameters, dW_{1t} and dW_{2t} are Wiener processes and the correlation between them is ρ. The Heston model yields a closed form solution for prices of European options (we refer to the original paper for the formulae), which is the formula for $\widetilde{C}$ in Eq. (3).

Besides a time series for $\theta(t)$ and Δ, option prices depend on a time series for the volatility $v(t)$ and five other parameters: α, the long run value of $v(t)$; κ, the speed of mean reversion; ξ, the variance in the process for the volatility $v(t)$; ρ, the correlation between both Wiener processes; and λ, the price of volatility.

4. Data and estimation

4.1. Data

Our baseline estimations employ data on stock options negotiated at the Sao Paulo Stock Exchange (BM&FBovespa).[15] Stock options traded in the Sao Paulo exchange mature on Monday in the 3rd week of each month. We use daily data on options with maturity on November 17, the first maturity date following the election. This data set comprises 2349 data points in the 6-week period from October 6 to November 14. The first 3 weeks (15 days) of the sample cover the period between the first and second ballots, while the last 3 weeks of the sample occur after the second ballot.

The options in this dataset refer to preference shares of Petrobras, which have priority in regards to dividends but no voting rights. Ordinary shares (with voting rights) are also traded at the Sao Paulo exchange, but the market for options on these shares is much thinner. All puts are European. There are both American and European calls in our sample, but since the strike price is adjusted to offset the effect of dividends, the well known result in Merton (1973) shows either type of call should be worth the same.[16]

Table 1 shows we have many data points per day, implying that options with a large range of strike prices are traded, especially before the election, when we have on average 86 observations per day in our data set. This is crucial for the identification of Δ (see the discussion in Section 4.3). Most of the options traded in this market are calls.

Table 1 also shows that trade on options with large strike prices is severely reduced after the election. For example, options with strike price larger than BRL 22 represent 60% of the volume of traded options

[11] Had the economy in 2014 been an important factor in the election, Ms. Rousseff would not have been reelected. The official line of Ms. Rousseff's campaign was that Brazil was suffering from a world economic crisis, implying that the weak economic activity was not related to her government policies. Her campaign was all about the 12 years of government by the Workers Party, which included the 8 years under her predecessor Luis Inacio Lula da Silva. The economy had done relatively well in those 12 years, but very badly under Ms. Rousseff (especially if her first year is excluded) and news about the economy in a few weeks would not change that.

[12] In 2016, exports were 12.5% of GDP.

[13] As an illustration, in the 6-week period we focus on, trading volume of Petrobras American Depositary Receipts in New York was 78% larger than its counterpart in Sao Paulo (including both ordinary and preferred stock).

[14] Indeed, assuming that S_{low} behaves as in the Black and Scholes model yields larger estimates of Δ. See the working paper version of Carvalho and Guimaraes (2016).

[15] Petrobras represents a significant share of the Brazilian stock market index (around 13% of the index at the beginning of 2014 and around 8% of the index at the beginning of 2015) and much of the market for stock options.

[16] Indeed, there is a negligible amount of early exercises in the week before maturity.

Table 1
Data description.

		Pre-election	Post-election
Data points per day		86.4	70.2
	Calls	52.3	40.2
	Puts	34.1	30.0
Strike:	K < 15	10.0	17.7
	15 < K < 20	31.1	30.6
	20 < K < 25	26.7	15.3
	K > 25	18.6	6.5
Volume/day (BRL millions)		1.71	0.67
Calls (% of volume)		89.4%	70.8%
Strike > 20 (% of volume)		76.4%	2.4%
Strike > 22 (% of volume)		60.1%	0.9%

in the pre-election period; this number plummets to around 1% after the election. This suggests that Ms. Rousseff's victory made clear those strike prices would not be reached. In contrast, trade on options with low strike price increases after the election. The number of options with strike prices below BRL 15 is 10 on an average day before the election and 17.7 on an average day after the election.

The value of Petrobras is distributed among 5.6 billion outstanding preference shares and 7.44 billion ordinary shares. On Monday October 27, right after the election, the closing price of preference shares was BRL 14.29, while the closing price of ordinary shares was BRL 13.92. Hence, Petrobras was worth BRL 183.6 billion on the first date after the 2014 Brazilian election, which was then equivalent to USD 72.45 billion (using the exchange rate from October 27).[17]

Each observation i corresponds to an option with a certain strike price in a given date. We have daily information on the price of the last trade for each option. For the spot price of Petrobras, we used the price of the last trade at each date. For the interest rate, we used the interbank short-term rate (CDI).

In one specification, we use data on options on the stock market index (Ibovespa). We also have daily data on the last trade of these options, but they mature only on December 17th. In the 6-week period from October 6 to November 14, we have 703 data points, which yields an average of only 23 traded options per day. By itself, this data set is too small, but combined with the data on Petrobras options, it yields useful information.

We also estimate the model using data on options traded at the New York Stock Exchange (NYSE). We use the closing price of options with maturity on November 22, the first maturity date following the election. As in our baseline estimations, we consider the 6-week period from October 6 to November 14. Owing to holidays on October 13 (Columbus Day on Sunday October 12) and November 11 (Veterans Day), there are 28 working days in this period. There are not so many strike prices, so our data base comprises 1070 data points, which yields an average of 38 observations per day in our dataset.[18]

The options in this dataset refer to ordinary shares of Petrobras. Moreover, prices are quoted in US Dollars, not in Brazilian Reais. These are the two important differences between our data on options traded in Sao Paulo and in New York. All options negotiated in the NYSE are American. In principle, this could add an extra layer of complexity to the option-pricing problem. However, since the US interest rate is virtually zero in this period and it was known there would be no dividend payments, American and European options should be worth the same.

[17] For comparison, in 2014, market capitalization of Exxon Mobil was USD 416 billion, Royal Dutch Shell was worth USD 238 billion and British Petroleum was worth USD 156 billion.

[18] Considering the average between bid and ask prices instead of closing prices raises the size of our sample to 2358 data points in this 6-week period. However, the bid-ask spread is often quite wide, so estimating the model using the average between bid and ask prices yields similar but less accurate results.

4.2. Estimation

Define ϵ_i as the difference between observed and theoretical option prices

$$\epsilon_i \doteq (C_i^{obs} - C_i)w_i \tag{4}$$

where w_i is the weight on observation i. Our baseline specification uses $w_i = 1$ for all i, a usual procedure in the literature. However, a deviation of BRL 0.05 in the price of an option that costs BRL 0.10 is arguably less desirable than a similar deviation in the price of an option that costs BRL 10.00. Thus we also estimate the model attributing a larger weight to residuals for cheaper options.

In principle, one could estimate Δ, the five parameters from the Heston model and a time series for v and θ. However, our data is not able to identify all parameters of the Heston model. In particular, the standard errors for α and λ were always very large. Hence the price of volatility λ was set to zero and α, the long run variance of changes in the asset price, was set to match the time-series estimate in no-election times, 0.45^2. Importantly, the estimates of Δ are not at all sensitive to these choices.

We thus estimate three parameters of the Heston model (κ, ξ and ρ), Δ and a time series for $\theta(t)$ and $v(t)$. The estimates are found by non-linear least squares.

When options on the stock market index are used, we estimate only one series of reelection probabilities $\theta(t)$ (as they are the same for all assets), but two sets of parameters of the Heston model and two values of Δ (one for Petrobras and another for the stock market index). In this case, the weights w_i need to be adjusted to ensure that similar residuals of different assets have a similar impact on the estimation.

Standard errors are clustered on day and we apply the formula employed by *Stata* in the estimation of standard errors for non-linear models.[19] From Cameron and Miller (2011), the cluster-robust estimate of the asymptotic variance matrix of our estimator is

$$\widehat{V} = \frac{G(N-1)}{(G-1)(N-K)}(J'J)^{-1}\left(\sum_{g=1}^{G} J_g'\hat{u}_g\hat{u}_g'J_g\right)(J'J)^{-1} \tag{5}$$

where J is the matrix of partial derivatives of fitted option prices with respect to parameters (the Jacobian of the non-linear estimation), $\hat{u}$ is the vector of residuals, G is the number of clusters (i.e., the number of trading days in the sample), N is the number of observations and K the number of estimated parameters.

4.3. Discussion on identification

Options with different strike prices carry information about different moments of the price distribution and thus supply information about the probability density function of the underlying asset. If we knew the price of options for every strike price, we would be able to retrieve state price densities of the asset value with no further assumptions. As Breeden and Litzenberger (1978) have shown, the second derivative of option prices with respect to the strike price yields the probability density of the asset value under the assumption of risk neutrality.

However, a mechanic application of the result in Breeden and Litzenberger (1978) to our data set invariably leads to implausible probability density functions, with negative values for a large set of prices of the underlying asset. The market for options on Petrobras is not liquid enough to generate very accurate option prices for all strike prices. The problem is that small price deviations might have a large impact on the second derivative.[20] Hence, further assumptions – and

[19] Our conclusions are unchanged if we calculate standard errors in the standard way. See the working paper version of Carvalho and Guimaraes (2016).

[20] In other words, large differences in probability density functions might be associated with not very different option prices.

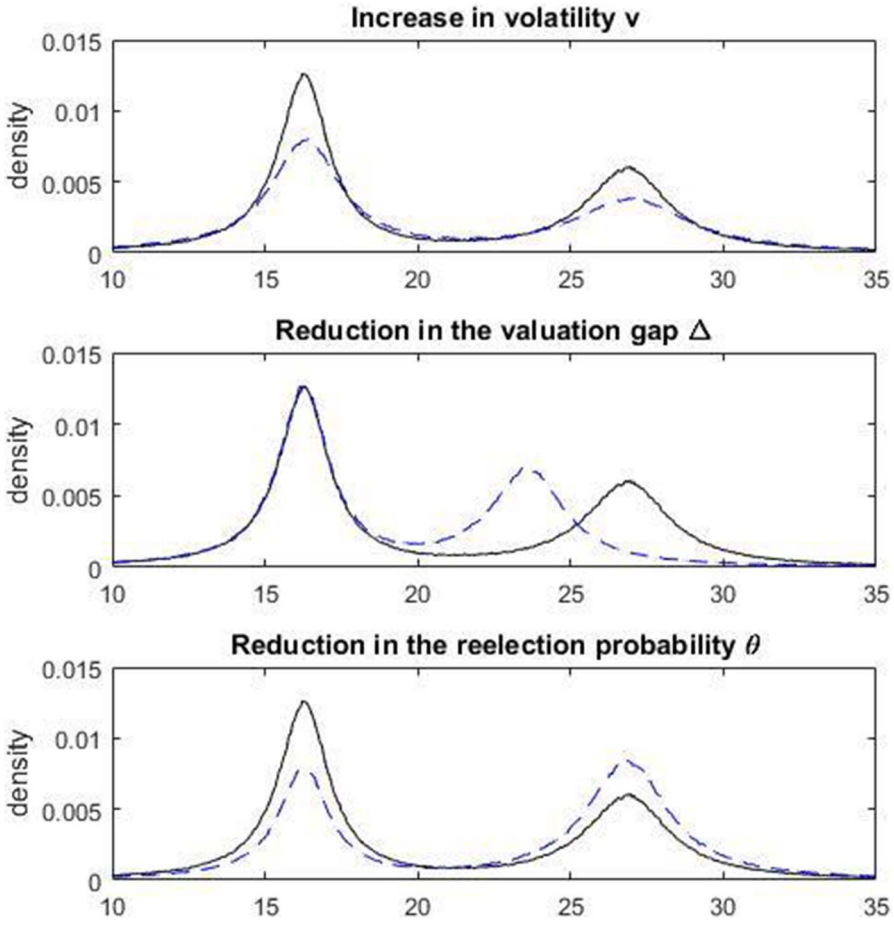

Fig. 2. Effects of v, Δ and θ on the probability density function.

data on options with many strike prices – are needed.

The model parameterizes the probability density function of the stock price. This allows us to identify Δ and θ. Fig. 2 helps understanding the intuition for identification by showing how the probability distribution of stock prices is affected by changes in Δ, θ and v, the variance of S_{low}. The solid line is the probability density for October 6 according to our baseline estimation and the dashed lines picture the density when one parameter is changed.

An increase in v spreads the density function, as illustrated in the top panel of Fig. 2. A larger v corresponds to more or larger shocks regarding the company business that are unrelated to the result of the election. Changes in world oil prices and news about success or failure of the company's projects are examples of such shocks.

An increase in Δ, corresponding to a larger increase in the value of Petrobras conditional on the *High* State, shifts the right side of the distribution of S further to the right, driving the peaks farther away. The opposite happens with a reduction in Δ, as shown in the middle panel of Fig. 2.

Last, the probability of the *Low* state θ moves according to news from polls, newspapers, debates, etc. Shocks to θ change the relative mass under each peak. A reduction in θ raises the odds of a higher realization of S, as illustrated in the bottom panel of Fig. 2.

Now consider a put with low strike price and a call with high strike price. An increase in v raises the price of both. An increase in Δ raises the price of the out-of-the-money call but does not affect the value of the low-strike put. In turn, an increase in θ raises the value of the put and reduces the price of the call.

This example considers only the volatility of the process for S_{low}, but the message applies to other parameters of the Heston model and to other diffusion processes. The key here is that changes in parameters of the diffusion model affect the probability distribution of S regardless of the election outcome. The parameters of the Heston model affect how thick the tails of the distribution are, but do not shift the right side of the distribution (like Δ) and do not change the relative mass under each peak (like θ).

A close election race helps us to identify Δ. If θ is close to 0 or 1, one of the outcomes will have little effect on option prices. In contrast, when $\theta \sim 1-\theta$, the probability density for the asset will be very different from the usual single-peaked distribution. Similarly, a large gap in valuation helps us to identify θ. If Δ is small, changes in θ will also have little effect in option prices, making it harder to detect the change in mass under different peaks of the distribution.

5. Results

Table 2 shows the estimates of Δ and parameters of the diffusion model for 5 different specifications using data on options traded in Sao Paulo. In the baseline estimation, (i) the probability of reelection $\theta(t)$ is set to 1 after the election; (ii) only data on Petrobras options are used; and (iii) all options are attributed the same weight, $w_i = 1$. The results are reported in the first column. The second column also estimates a vector $\theta(t)$ for dates after the election. The third column includes options on the stock market index (Ibovespa) in the data set to estimate the effect of the election on the stock market as a whole (Δ_{index}). In the fourth and fifth column, residuals are divided by the square root of the option price and by the option price, respectively. These last two specifications thus attribute a larger weight to out-of-the-money options, that are cheap but might carry important information about tail events. Tables with estimates of $\theta(t)$ and the variance of S_{low} are in Appendix C.

All estimates of θ in the pre-election period are statistically different

Table 2
Estimates using data from options traded in the Sao Paulo Stock Exchange. The first column shows results for our baseline specification: $\theta(t)$ is set to 1 after the election; only data on Petrobras options are used; and all options are attributed the same weight, $w_i = 1$. The second column shows results when post-election reelection probabilities are also estimated. The third column shows results when options on the stock market index are included in the estimation. The fourth and fifth columns show results when residuals are divided by the square root of the option price and by the option price, respectively. Robust standard errors are calculated using Eq. (5).

	Baseline	Estimates post-election θs	Includes market index	Square root weight	Proportional weight
Δ	1.651	1.650	1.652	1.697	1.705
	(0.018)	(0.018)	(0.018)	(0.023)	(0.023)
κ	6.2	2.7	7.2	88.1	145.4
	(13.8)	(16.2)	(14.2)	(24.6)	(67.9)
ξ	8.0	6.4	8.3	17.5	29.8
	(3.5)	(3.9)	(3.6)	(3.2)	(12.3)
ρ	−0.26	−0.33	−0.26	−0.12	−0.04
	(0.08)	(0.08)	(0.07)	(0.03)	(0.02)
Δ_{index}			1.18		
			(0.00)		
κ_{index}			76		
			(12)		
ξ_{index}			5.2		
			(0.1)		
ρ_{index}			−0.24		
			(0.00)		
1/wi	1	1	P(27-Oct)	sqrt (C^{obs})	C^{obs}
Set θ(t) = 1 for t > 15	Yes	No	Yes	Yes	Yes

from 0 and from 1 and all estimates of Δ are much larger than 1. The model is thus detecting significant deviations from the standard Heston model.

The estimates of Δ reported in the first three columns are basically the same, 1.65. Attributing a larger weight to out-of-the-money options yields slightly larger estimates of Δ, around 1.70. In any case, the estimated gap in the value of preference shares of Petrobras is huge.

If the relation between prices of preference and ordinary shares were unaffected by the election result, Δ would give us the effect of the election on the value of Petrobras. However, as shown in Appendix B, the ratio of the preference share price to the ordinary share price varies systematically with the probability of reelection.

The baseline estimate of Δ implies that preference shares of Petrobras would be worth BRL 23.59, or around 65% more had Ms Rousseff lost the election. Using the results in Appendix B to estimate the counterfactual ratio between prices of preference and ordinary shares, we get that ordinary shares of Petrobras would be worth BRL 21.87, or around 57% more in the case of an opposition victory. A back of the envelope calculation implies that an opposition victory would have raised the value of Petrobras by USD 44 billion (BRL 111 billion). The company would be worth around 61% more if Ms. Rousseff had lost the election.[21] This figure goes up to around 65% when we use the estimates of Δ from the last two columns of Table 2.

This effect is larger than those usually found in the literature. Using data from Indonesia, Fisman (2001) estimates that in the event of Mr. Suharto's death, returns to firms with strong political connections would have been 23% lower than returns to the least-dependent-on-political-connections firms. Focusing on Malaysia, Johnson and Mitton (2003) find that political connections accounted for approximately 17% of the total market value of politically connected firms. Knight (2006) studies the effect of a win by Mr. Bush over Mr. Gore in the 2000 US election. The estimates for the increase in the value of Bush-favored

[21] This increase in the value of Petrobras corresponds to around 1.8% of Brazilian GDP or around 5% of the market capitalization of all listed Brazilian companies in 2014.

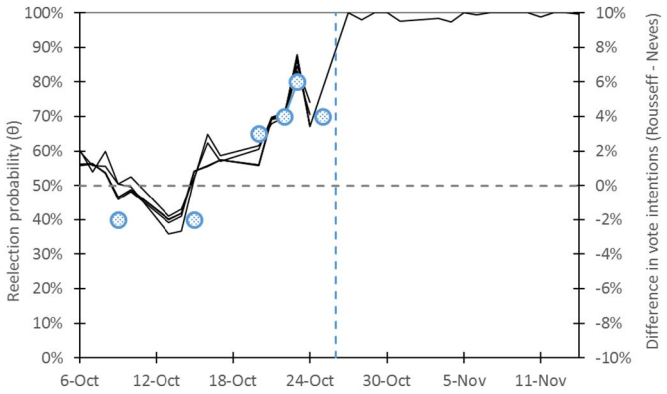

Fig. 3. Lines: Estimated probabilities of Ms. Rousseff's reelection using data from options traded in Sao Paulo (left axis). Circles: Difference in vote intentions for Ms. Rousseff and Mr. Neves according to DataFolha (right axis). The vertical dashed line indicates election day.

firms relative to Gore-favored firms range from 9% to 16%. The effects found by Imai and Shelton (2011) in Taiwan are smaller.

The estimates for the path of reelection probabilities $\theta(t)$ are plot in Fig. 3 (left axis). Reassuringly, all estimates of $\theta(t)$ after election day are equal or very close to 100% (see also Table 5 in Appendix C). Besides working as a sanity test of the model, this allows us to identify the reelection of Ms. Rousseff as the outcome associated with the *Low* state.[22] The circles in Fig. 3 show the advantage of Ms. Rousseff over Mr. Neves according to opinion polls by Datafolha (right axis).[23] Owing to the very large expected impact of the election on asset prices, financial institutions were hiring pollsters to get daily information on the odds of reelection, so the data from opinion polls released to the public, shown in Fig. 3, are just part of the information available for players in financial markets. These data are in broad agreement with our estimates of reelection probabilities.

Our estimates of $\theta(t)$ in the first few days after the election, around 0.55, show a slight advantage for the incumbent Ms. Rousseff. She had beaten Mr. Neves in the first ballot by 8 percentage points (41.59% to 33.55%), but most of the remaining voters were expected to shift their support to Mr. Neves (which indeed happened). Hence this promised to be one of the closest presidential races in Brazilian history.

The first opinion polls showed a (statistically insignificant) advantage for Mr. Neves. Accordingly, our estimates of reelection probabilities go below 50% on October 9, the 4th day in our sample. A week later, reelection probabilities are again slightly above 50%, indicating a slight advantage for Ms. Rousseff. Notwithstanding these relatively small fluctuations, in the first two weeks after the first ballot, estimated probabilities of reelection oscillate between 40% and 60% with both candidates virtually tied in opinion polls.

Things changed in the last week before the second ballot. On Monday October 20, opinion polls started to show Ms. Rousseff ahead by a small margin. On Thursday October 23, Datafolha showed her winning by 6 percentage points, and our estimates of the reelection probability reach their peak on that day. Polls released on Friday showed a slight reduction in Ms. Rousseff advantage, setting a tense grand finale to a thrilling election. On Sunday October 26, the race came to a close with Ms. Rousseff beating Mr. Neves by three percentage points.

The third column of Table 2 shows results for the specification with options on Petrobras and on the stock market index. Residuals are divided by the price of the underlying asset on October 27, so each option

[22] The model with $\theta = 1$ is isomorphic to the model with $\theta = 0$ and S_{low} divided by Δ. However, imposing $\theta(t) = 0$ after election day implies an implausibly large downward jump in S_{low} on election day, while $\theta = 1$ after election day yields a smooth path of S_{low}.

[23] The two main pollsters in Brazil are Ibope and Datafolha. Their polls in this period are very similar, but Datafolha yields more data points.

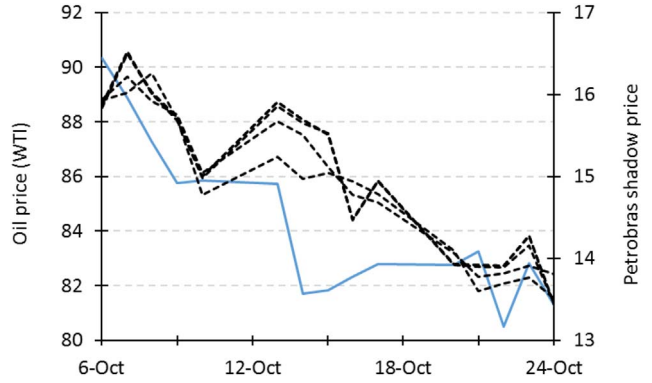

Fig. 4. Solid line: oil price, WTI (left axis). Dashed lines: Estimated price of Petrobras shares conditional on Ms. Rousseff's reelection, $S_{low}(t)$ (right axis).

on a given asset has the same weight. The estimates for Δ and θ are very similar to those in our baseline estimation. In other words, using the values of θ from the first column of Table 2 and estimating only parameters specific to the stock market index would yield very similar results. Intuitively, since there are relatively few data points, there is not much information about the underlying probability density function, so the options on Ibovespa 'have little say' on what the common parameters (the reelection probabilities $\theta(t)$) should be.[24]

The estimate of Δ_{index} indicates that an opposition victory would boost the stock market index by around 18%. This is a very large effect – the comparable number for the U.S. market from Snowberg et al. (2007) is 2–3% – but still much lower than the 60%–65% estimated increase in the value of Petrobras. This highlights the vulnerability of Petrobras to political risk.

The parameters of the Heston model vary a lot across specifications and are often insignificant. Intuitively, the Heston model yields a leptokurtic distribution of S_{low}, which is consistent with the data, and different parameter configurations alter the shape of the distribution. However, in the case of options maturing in less than 6 weeks, these alterations are very mild – and are not accurately identified by our estimation procedure with the available data. Nevertheless, the estimates of our parameters of interest, Δ and $\theta(t)$ are remarkably similar across different estimation procedures.

Fig. 4 plots the shadow price of Petrobras conditional on reelection, $S_{low}(t)$, implied by the estimates of $\theta(t)$ and Δ in each of our five specifications (dashed lines, right axis). It falls from around BRL 16 in the first days of the sample to around BRL 14 right before the election. This change is very small if compared to the fall in the observed asset price $S^*(t)$ shown in Fig. 1, but is still a very large drop in a three-week period. However, as shown in Fig. 4 (solid line, left axis), oil prices also went down by about 10% during this period. The changes in $S_{low}(t)$ captured by the model appear to reflect the downward trajectory of oil prices.

On October 27, in the aftermath of the election, the closing price of a Petrobras share was BRL 14.29 (after reaching a minimum value of BRL 13.76). Our estimates for $S_{low}(t)$ on October 24 range from BRL 13.42 to BRL 13.80. This difference is at least in part explained by the news on the first trading day after the election. Newspapers on October 27 had rumours that Ms. Rousseff would choose a market-friendly Minister of Finance. This could suggest a change in policies (including the 'Law of Local Content' and the control over oil prices) that would affect the valuation of Petrobras. Weeks later, the rumours would be confirmed, as Mr. Joaquim Levy, a banker with a PhD in Economics from U Chicago would be appointed Minister of Finance.

This suggests that uncertainty about the effect of the election on the value of Petrobras could be important. Uncertainty that is common to both candidates could be captured by a mean-zero normal jump in the log price of the asset. Since we are estimating one variance parameter per day, including a (log-normal) jump would be redundant. In the current estimation, this uncertainty is captured by the variance of S_{low}, and a one-time jump would imply larger estimated variance parameters as we approached election day.[25] This is exactly what we obtain (results for the variance are reported on Table 7 in Appendix C).[26]

Table 3
Estimates using data from options traded in the New York Stock Exchange. The first column shows results of our baseline specification: $\theta(t)$ is set to 1 after the election and all options are attributed the same weight, $w_i = 1$. The second column shows results when post-election reelection probabilities are also estimated. The third and fourth columns show results when residuals are divided by the square root of the option price and by the option price, respectively. Robust standard errors calculated using Eq. (5).

	Baseline	Estimates post-election θs	Square root weight	Proportional weight
Δ	1.792	1.792	1.840	1.797
	(0.025)	(0.025)	(0.025)	(0.042)
κ	35.8	13.6	174.7	174.2
	(31.3)	(31.3)	(9.1)	(47.8)
ξ	8.6	3.9	25.8	25.9
	(4.9)	(3.8)	(1.3)	(5.0)
ρ	− 0.08	− 0.21	0.06	0.07
	(0.07)	(0.11)	(0.00)	(0.01)
$1/w_i$	1	1	sqrt(C^{obs})	C^{obs}
Set $\theta(t) = 1$ for $t > 15$	Yes	No	Yes	Yes

5.1. Results using options traded in the NYSE

Table 3 shows the results when we repeat the estimations reported in Table 2 using data on Petrobras options traded in the NYSE instead of those negotiated in Sao Paulo. As before, in the baseline estimation, the probability of reelection $\theta(t)$ is set to 1 after the election and all options are attributed the same weight, $w_i = 1$. The results are reported in the first column. The second column also estimates a vector $\theta(t)$ for dates after the election. The third and fourth columns show results when residuals are divided by the square root of the option price and by the option price, respectively. Tables with estimates of $\theta(t)$ are in Appendix C.

The estimates of Δ in Tables 2 and 3 are not supposed to be the same because options traded in New York refer to ordinary shares and are priced in US Dollars, while options traded in Sao Paulo refer to preference shares and are priced in Brazilian Reais. Owing to the impact of the election on the exchange rate and on the ratio of the preference share price to the ordinary share price, the estimates of Δ in Tables 2 and 3 should indeed be different.

In Appendix B, we estimate that an opposition victory would raise the ratio of the preference share price to the ordinary share price by around 4%. Using this figure, the estimates of the valuation gap of preference shares in Table 2 would imply estimates of the valuation gap of ordinary shares ranging between 1.59 and 1.64. This is around 10% less than the estimates of Δ in Table 3, suggesting that an opposition victory would multiply the Real-Dollar exchange rate by around 0.90.

[24] In an analogy with a linear regression, it is as if we considered a new data set (together with an old one) and imposed that the coefficient β_1 had to be the same for both data sets. Since there is not much variation in the regressor x_1 in the new data set, the estimate of β_1 will still be mostly determined by the old data set. However, once we have β_1 for the new data set, we can get a decent estimation of the intercept.

[25] In the absence of a one-time jump, a variance parameter $v(t)$ implies a variance of S_{low} on maturity day (T) equal to $v(t)(T - t)$. With a one-time jump, the variance is $v(t)(T - t) + \sigma^2$, where σ^2 is the variance of the jump. Our estimator of $v(t)$ would then converge to $v(t) + \sigma^2/(T - t)$.

[26] One might also conjecture that different election outcomes would be associated with different levels of uncertainty. The model can be extended to include a candidate-specific volatility term, but separating this from normal disturbances would require very accurate data.

Table 4
Estimates of Δ via non-linear least squares, from Eq. (6). The values of $\theta(t)$ are taken from the respective columns of Tables 5 and 6 in Appendix C. (P) denotes preference shares and (O) denotes ordinary shares. The signs ***, ** and * indicate rejection of the null hypothesis H_0:Δ = 1 at the levels of significance 1%, 5% and 10%, respectively.

Series of reelection probabilities		Data from São Paulo					Data from New York	
		Baseline	Includes Oct-27	Post-election θs	Square root weight	Proportional weight	Baseline	Square root weight
State-controlled companies								
Petrobras (P)	Oil	1.44***	1.42***	1.46***	1.71***	1.55***	1.65***	1.41
		(0.12)	(0.08)	(0.12)	(0.07)	(0.08)	(0.26)	(0.26)
Banco do Brasil (O)	Banking	1.40***	1.29***	1.42***	1.62***	1.46***	1.63**	1.38
		(0.10)	(0.08)	(0.11)	(0.08)	(0.09)	(0.23)	(0.24)
Petrobras (O)	Oil	1.38***	1.37***	1.40***	1.65***	1.51***	1.36	1.23
		(0.11)	(0.08)	(0.12)	(0.07)	(0.07)	(0.21)	(0.20)
Eletrobras (O)	Electricity	1.33***	1.32***	1.34***	1.49***	1.35***	1.52*	1.36
		(0.09)	(0.06)	(0.09)	(0.09)	(0.09)	(0.25)	(0.24)
BB Seguridade (O)	Insurance	1.07	1.02	1.08	1.16***	1.12***	1.17*	1.09
		(0.04)	(0.04)	(0.05)	(0.04)	(0.04)	(0.08)	(0.08)
Private companies								
Bovespa (O)	Finance	1.36***	1.22**	1.37***	1.56***	1.41***	1.48**	1.33
		(0.09)	(0.08)	(0.10)	(0.07)	(0.08)	(0.21)	(0.21)
Bradesco (P)	Banking	1.31***	1.20***	1.33***	1.48***	1.36***	1.31	1.15
		(0.08)	(0.07)	(0.08)	(0.07)	(0.07)	(0.21)	(0.20)
Itaú (P)	Banking	1.27***	1.20***	1.29***	1.42***	1.32***	1.32*	1.19
		(0.07)	(0.05)	(0.07)	(0.06)	(0.06)	(0.18)	(0.17)
Itaú, holding (P)	Banking	1.26***	1.18***	1.27***	1.41***	1.31***	1.34*	1.15
		(0.07)	(0.05)	(0.07)	(0.05)	(0.06)	(0.18)	(0.18)
Bradesco (O)	Banking	1.24**	1.19***	1.25***	1.40***	1.31***	1.30	1.18
		(0.08)	(0.06)	(0.08)	(0.07)	(0.06)	(0.17)	(0.16)
CCR (O)	Roads	1.23***	1.07	1.24***	1.34***	1.25***	1.14	1.11
		(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.11)	(0.10)
JBS (O)	Food	1.16*	1.10	1.17*	1.31***	1.22***	1.09	1.02
		(0.08)	(0.06)	(0.08)	(0.07)	(0.07)	(0.13)	(0.12)
Ultrapar (O)	Fuels	1.16**	1.10**	1.17**	1.23***	1.15**	1.22	1.09
		(0.06)	(0.04)	(0.06)	(0.06)	(0.06)	(0.16)	(0.15)
Kroton (O)	Education	1.15***	0.97	1.15***	1.19***	1.13**	1.12	1.03
		(0.05)	(0.06)	(0.05)	(0.06)	(0.05)	(0.10)	(0.09)
CBD (P)	Retail	1.14**	1.13***	1.15**	1.19***	1.12**	1.09	0.96
		(0.05)	(0.04)	(0.05)	(0.06)	(0.06)	(0.18)	(0.16)
Ambev (O)	Beverages	1.14***	1.08**	1.15***	1.21***	1.16***	1.12	1.15
		(0.04)	(0.03)	(0.04)	(0.05)	(0.04)	(0.11)	(0.09)
BRF (O)	Food	1.09	1.05	1.09*	1.17***	1.11**	1.12	1.15
		(0.05)	(0.04)	(0.05)	(0.05)	(0.05)	(0.11)	(0.09)
Cielo (O)	Finance	1.07	0.98	1.07	1.23**	1.18**	1.08	1.03
		(0.09)	(0.07)	(0.09)	(0.09)	(0.08)	(0.11)	(0.10)
Vale (O)	Mining	1.00	1.06	1.00	1.07	1.06	1.31*	1.11
		(0.06)	(0.05)	(0.06)	(0.07)	(0.06)	(0.15)	(0.15)
Vale (O)	Mining	0.99	1.05	0.99	1.07	1.06	1.11	1.06
		(0.06)	(0.05)	(0.06)	(0.07)	(0.06)	(0.11)	(0.10)
Embraer (O)	Airplanes	0.94	0.92*	0.93	0.88	0.90	0.85	0.89
		(0.06)	(0.05)	(0.07)	(0.08)	(0.06)	(0.12)	(0.11)
Exchange rate								
Real/dollar		0.94**	0.94***	0.93**	0.89***	0.92***	0.91	0.94
		(0.03)	(0.02)	(0.03)	(0.03)	(0.03)	(0.06)	(0.05)

This is a bit lower than most estimates reported in Table 4 (bottom line) but well within their confidence intervals. The bottom line is that the estimates of Δ based on data from options negotiated in the NYSE are very similar to those based on data from options traded in Sao Paulo.

The estimates of the probability of reelection $\theta(t)$ using data from options traded in New York should be very similar to those in Fig. 3.[27] Fig. 5 shows they are indeed (see also Tables 5 and 6 in Appendix C). The dashed line shows the baseline estimates of $\theta(t)$ from Fig. 3, while the solid lines are the estimated probabilities of reelection using data from the NYSE. The main differences are on dates right before the election, October 23 and 24, but they are not large. Note that there is no data from the NYSE on Monday October 13 (it is a holiday in the US). As in Fig. 3, the estimates of $\theta(t)$ after election day are equal or very close to 100%.

[27] Slightly different closing times of the exchanges in Sao Paulo and New York could generate some difference between estimates.

As in Table 2, the estimates of parameters of the Heston model reported in Table 3 vary a lot across specifications and are often insignificant. Estimates of the variance $v(t)$ are even less accurate than those from Table 7 in Appendix C, especially before the election (available upon request).

5.2. The effect of the election on other asset prices

The lack of available data on options with many different strike prices for companies other than Petrobras prevents us from extending our estimation to a wider set of firms. Nevertheless, our estimated reelection probabilities can be used to assess the impact of Ms. Rousseff's reelection on other asset prices. We now estimate the effect of the election on the exchange rate and on the 20 most traded shares in the Brazilian stock market. Since there are not many state-controlled companies in the list, Eletrobras (a large state-controlled electricity company that did not make it into the top-20) was included in the

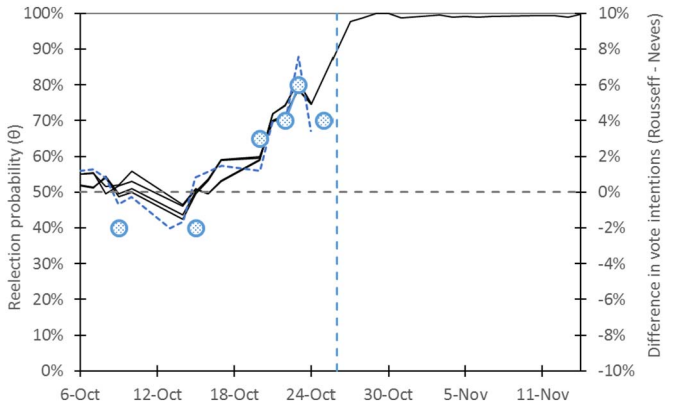

Fig. 5. Solid lines: Estimated reelection probabilities using data from options traded in New York (left axis). Dashed line: Baseline estimates of reelection probabilities using data from options traded in Sao Paulo (left axis). Circles: Difference in vote intentions for Ms. Rousseff and Mr. Neves according to DataFolha (right axis). The vertical dashed line indicates election day.

sample.

From Eq. (1), we obtain

$$\log(S^*(t)) = \log[S_{low}(t)] + \log[\theta(t) + (1 - \theta(t))\Delta]$$

where Δ is the effect on the asset price of a victory by Mr. Neves. Taking first differences and assuming that $\varepsilon(t) = \log(S_{low}(t)) - \log(S_{low}(t-1))$ is a mean-zero error term, we get that

$$\log\left(\frac{S^*(t)}{S^*(t-1)}\right) = \log\left(\frac{\theta(t) + (1 - \theta(t))\Delta}{\theta(t-1) + (1 - \theta(t-1))\Delta}\right) + \varepsilon(t) \quad (6)$$

Using Eq. (6), our estimates for the probability of reelection $\theta(t)$ and daily data on asset prices, we estimate Δ, for each asset, by non-linear least squares. For consistency with the option data, we use the closing price of each asset.

From October 6 to October 24, we have only 14 data points using data from options negotiated in Sao Paulo and only 13 data points using data from NYSE-traded options (there is no estimate for $\theta(t)$ on October 13). In order to get an extra data point, we can also include asset price data from October 27 (the Monday following the election) even though they are affected by news about the plans of the reelected president not captured by our option data. Either way, we have few observations. Moreover, our measures of $\theta(t)$ are subject to some error, so our estimator of Δ might suffer from attenuation bias. Nevertheless, we find some strong and significant effects of reelection on asset prices.

Table 4 shows the estimates for Δ. Different columns report results based on different series of estimated reelection probabilities $\theta(t)$ from Tables 5 and 6 in Appendix C.[28] The second column shows results when data from asset prices on October 27 are included in the sample (using our baseline estimates of θ). All other columns show results with data until October 24. The series of estimated reelection probabilities look quite similar to each other, but they generate significant differences in the series of $\theta(t) - \theta(t-1)$. Hence, they lead to different estimates of valuation gaps and different standard errors.

The estimates show that Ms. Rousseff's reelection had a strong negative impact on many companies. The effects are particularly strong in the banking sector, but are also large for a variety of firms in different sectors, including Bovespa (the stock exchange), CCR (transportation), Kroton (education), CBD (supermarkets), Ambev (beer), Ultrapar (fuel distribution) and JBS (food). The only possible exception is Embraer, the Brazilian aircraft manufacturer. The effects are also large in absolute terms, perhaps around USD 15 billion for Itau and USD 10 billion for Banco do Brasil, Bradesco and Ambev. Moreover, the Brazilian currency is estimated to have lost between 6% and 11% of its value owing to Ms. Rousseff's reelection.

However, the estimated effects on private companies are never as strong as the effects on Petrobras. Interestingly, Banco do Brasil, the Brazilian state bank, and Eletrobras, the state electricity company, are also very strongly affected by the election. The overall effect on the stock market index, estimated around 1.18, looks small in comparison. While the magnitudes might look surprising, some effect was indeed expected. For example, in 2012, Ms. Rousseff grabbed the headlines by coaxing Banco do Brasil (and other state banks) to reduce interest rates to borrowers. This is a clear example of a state-owned firm focusing on objectives other than maximizing profits. The result is thus consistent with the idea that state-controlled firms are particularly vulnerable to political risk.

The estimated Δ for preferred shares of Petrobras ranges between 1.42 and 1.71, depending on the series of reelection probabilities employed in the estimation and on whether data from October 27 is included in the sample.[29] In most cases, the estimates for Δ in Table 4 are smaller than the corresponding estimates in Table 2, and we conjecture that attenuation bias might be affecting our estimation. Still, the results in Table 4 agree with the hypothesis that an opposition win would have had a large effect on asset prices and that it would have been particularly important for state-controlled companies.

6. Concluding remarks

This paper proposes a method to study the effect of election outcomes on asset prices. We extend a standard asset diffusion model to capture the effect of an election and estimate it with data on stock options. Although our focus has been on presidential races, the model can be applied to other cases of anticipated events with binary outcomes. Besides elections and referenda, possible examples include antitrust decisions about mergers or acquisitions and health agency decisions about whether a drug can be sold to consumers.

The value of Petrobras is subject to huge political risk. Our results show that Petrobras shares would be worth around 60%–65% more had Ms. Rousseff lost the presidential election. One implication of this paper is that the risk of de-facto expropriation of minority shareholders can be strongly affected not only by slow moving institutional factors but also by changes in government via elections.

[28] Some specifications yield almost identical series of reelection probabilities and thus generate very similar estimates of the effects of the election on asset prices. Hence results for some specifications are omitted.

[29] On October27, markets seemed less pessimistic than expected, so our estimate for Δ including data from October 27 should indeed be smaller than the results in Table 2.

Appendix A. The formula for the option price

Under risk neutrality, the price of a call option with strike K, maturity T and spot price S_t^* is

$$C(S_t^*) = e^{-\int_t^T r_u du}\,\mathbb{E}\left[S_T^* - K | S_T^* \geq K,\, I_t\right]$$

Using Eq. (1),

$$\begin{aligned}\mathbb{E}\left[S_T^* - K\,|S_T^* \geq K,\, I_t\right] &= \mathbb{E}\left[\theta(t)S_{low} + (1-\theta)\Delta S_{low} - K\,|S_T^* \geq K,\, I_t\right]\\ &= \mathbb{E}\left[\theta(t)(S_{low} - K)|S_T^* \geq K,\, I_t\right] +\\ &\quad + \mathbb{E}\left[(1-\theta(t))(\Delta S_{low} - K)|S_T^* \geq K,\, I_t\right]\end{aligned}$$

The assumption that shocks to $\theta(t)$ and shocks to S_{low} are uncorrelated implies that

$$\mathbb{E}\left[\theta(t)(S_{low} - K)|S_T^* \geq K,\, I_t\right] = \theta(t)\mathbb{E}\left[(S_{low} - K)|S_T^* \geq K,\, I_t\right]$$

and

$$\mathbb{E}\left[(1-\theta(t))(\Delta S_{low} - K)|S_T^* \geq K,\, I_t\right] = (1-\theta(t))\mathbb{E}\left[(\Delta S_{low} - K)|S_T^* \geq K,\, I_t\right]$$

Since $\mathbb{E}\left[(S_{low} - K)|S_T^* \geq K,\, I_t\right] = C(S_{low}(t))$ and $\mathbb{E}\left[(\Delta S_{low} - K)|S_T^* \geq K,\, I_t\right] = C(S_{high}(t))$, we get the expression in Eq. (2).

Appendix B and C. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jpubeco.2018.02.002.

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