Information Frictions, Partial Defaults, And Sovereign Spreads ⋆

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Abstract. We study the reputational cost of sovereign default. We analyze policies that indirectly dilute the real value of debt, such as an underreport of inflation in the case of inflation-linked bonds. This type of policy undercuts a government's reputation of being a good borrower. In the empirical section, we measure the short-run costs of losing reputation in international debt markets and use these estimates to discipline a quantitative model. Taking Argentina's 2007 systematic misreport of inflation as a case study, we find that a 1pp change in inflation tampering induces a 10% increase in spreads. In our model, the type of government is time varying and private information. The government can engage in partial-default policies that are not perfectly observable by lenders. We find that incentives to misreport inflation are state contingent, being more appealing in good times. In bad times, spreads are more sensitive to news and can increase significantly if investors detect the policy that leads to the partial default. The model is able to replicate the evolution of spreads for Argentina in 2007-2010, in particular, the observed decoupling from other countries in the region.

Keywords: Sovereign Default, Business Cycles, Interest Rates.

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1. Introduction

A puzzling and still open question in international macroeconomics is why governments choose to repay their external debt. Early work by Eaton and Gersovitz (1981) suggested that countries repay to avoid a deterioration in their reputation and the consequent exclusion from international credit markets. Bulow and Rogoff (1989) challenged this view and showed that, in the absence of additional default costs, reputation itself cannot support an equilibrium with positive debt levels. For this reason, the sovereign debt literature has focused on the various types of direct output losses triggered by a default in order to match the empirical moments on sovereign debt and spreads. This type of models, however, cannot explain why countries with similar macroeconomic fundamentals may significantly differ in terms of their borrowing costs in international markets. In this paper, we revisit the role of reputation as an explanation for this heterogeneity.

In our analysis, we consider non-standard policies from which the government can dilute its real stock of debt at the expense of its lenders. In particular, we focus on partial-default policies that are not perfectly observed by lenders. When detected, these policies erode the government's reputation with a resulting rise in borrowing costs. The type of non-standard policy depends on the nature of external debt. For nominal local currency debt, for example, the government could unexpectedly increase domestic inflation (for instance, above an announced target); for inflation-indexed bonds (IIBs), the government can underreport the true inflation rate in order to decrease its coupon payments; for growth-indexed bonds, the government could underreport the true value of GDP growth in order to reduce the interest burden. There are several cases in which governments have implemented this type of policies. Back in 2007, Argentina's government started a systematic tampering of inflation reports to, among other objectives, decrease the interest payments of inflation-linked bonds.[1] During the 1990s, Bulgaria's government misreported its output growth by choosing different definitions of GDP, in order to reduce its GDP-linked bonds interest payments. Poor data quality could also have induced a similar situation in Bosnia and Herzegovina during the 1990s.[2]

To better understand the mechanisms through which these policies may affect the government's borrowing cost, we construct a reputational model in the spirit of Kreps and Wilson

[1] A milder episode occurred later in 2016. In that case, the Argentine government (unilaterally) changed the inflation index to which inflation-linked bonds were indexed.

[2] See Sandleris et al. (2011) and Miyajima (2006) for an analysis of the cases of Bulgaria and Bosnia and Herzegovina.

(1980) and Milgrom and Roberts (1982) with uncertainty about the government type. We assume two types of governments which differ in their willingness to repay debt for a given combination of macroeconomic fundamentals. We refer to the market's assessment of this willingness to repay as reputation. When lenders detect a non-standard policy that dilutes the real stock of (indexed) debt, they adjust their perceived reputation of the government and therefore their perceived probability of an outright default. We first develop a two-period model to build intuition and then move to an infinite-horizon economy to analyze the underlying dynamics and interactions between the different variables in this economy.

We start by posing a two-period model to highlight the trade-offs at hand. The model is general enough to accommodate different non-conventional policies through which the government can partially default on its obligations. We consider a small-open economy with incomplete markets and with a benevolent government that seeks to maximize the expected utility of the representative consumer. The government faces a deterministic initial level of indexed debt B that matures at the end of period 2. We assume that the government is subject to an exogenous short-term debt issuance obligation b that occurs at the end of period 1. Its price, q_b, depends on the government's reputation in international markets. There are two types of government (patient and impatient) and two different policies. The first policy is standard and it involves defaulting on all the government's liabilities. By doing so, a government incurs in a random output cost. The second policy, $\tilde{\pi}$, is a non-conventional policy that affects the stock of indexed bonds, B. For instance, if B is the stock of inflation-linked bonds, $\tilde{\pi}$ would represent the misreport of the true inflation rate. We assume that $\tilde{\pi}$ is not directly observable by international lenders, reflecting that this type of policies may be hard to identify. For instance, lenders do not perfectly observe the true inflation rate. We assume that the patient government has commitment and it cannot default nor involve in non-conventional policies that partially dilute its stock of debt. Although imperfectly observed, the government's actions affect lenders beliefs about the government's type. If lenders, for instance, detect an inflation misreport, they adjust their perceived probability of default, which increases the borrowing costs of the government in period 1 (i.e. the price q_b).

The two-period model provides two main results. The first one is that incentives to engage in non-conventional policies that dilute the real stock of debt are state contingent. In particular, we observe stronger incentives in "good times" than in "bad times". In bad times, sovereign spreads are more sensitive to the government's reputation, making the (ex-ante) cost of engaging in these policies higher. The second result is that the government's actions are heavily influenced by the beliefs of market participants, a result that resembles the one in Cole and Kehoe (2000). As lenders assign a worse reputation to the government, we find that the government has higher incentives to implement these non-conventional policies, because the associated costs are smaller (i.e. borrowing costs do not react much).

Motivated by the predictions of the model, in the empirical section we measure the short-run costs of losing reputation in terms of larger borrowing costs. To this end, we use the Argentine 2007-2012 episode of inflation tampering as a case study. This episode can be understood as an indirect partial default on the stock of inflation-linked bonds. During this period, the stock of inflation-indexed debt accounted for almost a quarter of the entire stock of debt so that the sequence of misreports actually had a great impact over the government's fiscal accounts. From 2007 to 2010, by misreporting its inflation rate, Argentina decreased its inflation-linked bonds payments by nearly \$3.2 billion, which accounts to around 1% of its GDP.

An important observation of the empirical section is that, although Argentina had similar macroeconomic fundamentals to other countries in the region, its spreads began to significantly decouple from those of the region exactly at the time when the inflation tampering began. This suggests that the sequence of inflation misreports had a strong negative impact over Argentina's reputation. Assessing the causal effect of inflation tampering on Argentina's spreads, however, poses an empirical challenge, since inflation tampering may be the response to a rise in spreads. To address this concern, we adopt a heteroskedasticity-based identification strategy (Rigobon and Sack (2004)) and find that a 1pp underreport on inflation leads to a $10-14\%$ increase in spreads on the short run.

In the quantitative section, we use the estimated short-run costs of inflation tampering to discipline our infinite-horizon model. We use the model to quantify the long-run costs of losing reputation. A key takeaway from the analysis is that the dynamics of reputation are quite persistent. This feature is actually relevant to replicate the observed evolution of Argentina's spreads after 2007. In particular, we are able to match the observed excess sensitivity of Argentina's spreads during the 2008 crisis, as well as the posterior decoupling from the rest of the region.

Literature Review

Our paper contributes to several strands of the literature. First, it connects to the quantitative literature analyzing governments' incentives to repay their debt. The majority of the literature follows Arellano (2008) and Aguiar and Gopinath (2006) by assuming exogenous default costs on output to sustain reasonable debt levels. Several other authors, such as Sandleris (2008) and Phan (2017), have focused on debt repayment as a stategic signaling device about the economy's fundamentals. Alternatively, debt repayment could be used to signal a government's type, as in Cole et al. (1995), D'Erasmo (2011), Onder (2016) and Barret (2016). The problem with standard debt policies as signaling devices is that government's actions are perfectly observable so the "good" government type can almost always differentiate itself. In this respect, we contribute by introducing non-standard policies that serve as signaling devices. Given that foreign investors can only observe a noisy signal of such policies, government's actions are not completely informative and lenders adjust their beliefs slowly.

Secondly, our paper is related to the literature initiated by Calvo (1988) that studies the effects of partial defaults on nominal debt through inflation. To the best of our knowledge, the effects of this type of policy on government's reputation have not been formally studied yet. Ottonello and Perez (2017) and Aguiar et al. (2013) assume an exogenous cost for inflating away the debt. This cost can reflect both real distortions generated by the higher inflation rate and a reduced-form proxy for the reputational cost to the government. Although we omit any type of distortionary costs, we provide a micro-foundation for the reputational costs.

Thirdly, the paper is related to a growing body of literature on indexed bonds. Durdu (2009), Sandleris et al. (2011) and Hatchondo and Martínez (2012) have all explored the benefits of completing markets by issuing state-contingent bonds in the context of a small open economy general equilibrium model. Despite those benefits, the literature has raised moral hazard concerns given a government's incentives to alter the reference index to reduce coupon payments.[3] In this paper, we address some of these concerns by analyzing the trade-offs of misreporting inflation and by describing under which conditions incentives to misreport are higher. Nevertheless, our analysis is partial in the sense that we are not studying how these moral hazard problems may impact on the price at issuance of these instruments.

Finally, our paper is also related to the empirical literature that estimates the response of financial variables to changes in government actions. Influential work by Bernanke and Kuttner (2005) and Rigobon and Sack (2004) estimated the effects that changes in the federal funds rate have on stock prices. More recently, Hebert and Schreger (2017) used a similar methodology to estimate the causal effect of Argentine sovereign default on domestic equity returns. Our

[3]See Eduardo et al. (2004) for a review. Another concern is the market liquidity of these bonds. Moretti (2020) shows that the welfare gains of introducing new type of debt instruments are significantly reduced once the liquidity premium is accounted for.

work contributes on this dimension by estimating the short-run effect of inflation misreport on Argentine sovereign spreads. We then make use of an infinite horizon quantitative model to provide a measure of the possible long-run effects.

The rest of the paper is structured as follows. Section 2 presents the two-period model. Section 3 describes the empirical analysis, based on the Argentina inflation-tampering episode. Section 4 presents the quantitative model. Section 5 concludes.

2. The 2-period Model

2.1. *Description of the Model*

We start by posing a two-period model whose intuition is useful to better understand the infinite horizon economy. The model is general enough to accommodate different types of policies through which the government can partially default on its obligations. Consider a small-open economy with incomplete markets that is populated by a representative consumer who faces an increasing and concave utility function. A benevolent government maximizes the expected utility of the representative consumer. Let (y_1, y_2) denote the deterministic endowment output for periods 1 and 2, respectively. The government faces a deterministic initial level of debt B that matures at the end of period 2. For a clearer exposition, we also assume that the government is subject to an exogenous short-term debt issuance obligation b that occurs at the end of period 1. This claim represents a promise to pay a unit of the consumption good next period. Although atypical in the sovereign debt literature, having exogenous debt issuance allows us to focus on a non-standard debt policy as described below.[4] In this economy, government's debt is held by risk neutral, perfectly competitive and deep-pocketed international lenders.

The government has two different policies. The first one is standard and it involves defaulting on all liabilities. By doing so, a government incurs in a random output cost given by $\phi_I \sim G(.)$. The second policy, denoted by $\tilde{\pi}$, captures any government policy that affects the stock of bonds B. For instance, if B is the stock of bonds denominated in the domestic currency, then $\tilde{\pi}$ represents a variation in the economy's inflation rate intended to inflate away this debt. If B is the stock of inflation-linked bonds, since the coupon payment of these bonds depends on the

[4] This exogenous amount can be interpreted as if the government has some level of public expenditures to finance via taxes and debt. Appendix B describes the model in which the government can choose the optimal bond policy. In such case, the bond policy also signals the type of government. By means of a quantitative example, we show that there exist multiple equilibria in such case.

government's report on inflation, $\tilde{\pi}$ would represent a misreport in the true value of inflation.[5] From now on, we follow this interpretation since it provides a suitable mapping to our empirical work. We assume that $\tilde{\pi} \in [-\bar{\pi}, 0]$ with the interpretation that $\tilde{\pi} < 0$ implies a partial default on behalf of the government. We also assume that $\tilde{\pi}$ is not directly observable by international lenders, reflecting that partial defaults can be hard to identify. Let π be the true inflation rate, $\hat{\pi}$ be the inflation announced by the government, and define $\tilde{\pi} = \hat{\pi} - \pi$ as the misreport. In real terms, the payments are

$$B \times \frac{1+\hat{\pi}}{1+\pi} \approx B\,(1+\tilde{\pi})$$

In the model, there are two types of government (P -patient- and I -impatient-) and the type is not publicly observable. The P-type has commitment so it never defaults or underreports inflation. The I-type can both underreport inflation and default. Since the bond policy is exogenous, these are the only two actions available for the government. Furthermore, these actions are used by international lenders to infer the type of government. When a government defaults, it incurs in a random output cost given by $\phi_I \sim G(.)$, which is realized at the beginning of period 2 (before the default decision) but it is unknown in period 1.

Figure 1 below describes the timing of events. We do so from the impatient government's point of view since it is the one that lacks commitment. The first period is divided into two stages. In the first stage, the government starts with a stock of inflation-indexed debt B, some prior (i.e. reputation) ζ of being the patient type, and chooses the misreport of inflation. After the government chooses $\tilde{\pi}$, lenders observe a noisy message $m = \{L, NL\}$, where L (lie) means the government underreported inflation and NL (no-lie) means that it reported inflation truthfully. We assume that the probability of receiving message $m = L$ is increasing in the government's under-report $(-\tilde{\pi})$.[6] Moreover, lenders have a conjecture $\tilde{\Pi}_I^*$ on what the misreport will be. Based on the observed message m and on the expectation $\tilde{\Pi}_I^*$, lenders then update their posterior ζ', using a Bayes-induced function: $\zeta' \equiv \zeta'(m, \tilde{\Pi}_I^*)$. In the second stage, the government issues short-term debt in accordance to the exogenous realization b.

[5]These bonds promise to pay one unit of the domestic currency plus an extra term that depends on the announced inflation by the government.

[6]The model can be categorized as a "one-shot noisy" signaling model. See Heinsalu (2016) for a quick review of these models and some applications.

Figure 1. Timing of Events: The two-period model

$t=1$				$t=2$	
	Stage 1		Stage 2		
Government starts with (B,ζ). Lenders have a conjecture $\tilde{\Pi}_I$.	The (impatient) government chooses $\tilde{\pi}$.	Based on $\tilde{\pi}$, message $m = \{L, NL\}$ is realized. Lenders update their posterior: $\zeta'\left(m, \tilde{\Pi}_I^\star\right)$.	Government issues b.	Default cost ϕ_I is realized.	The (impatient) government chooses to default or not.

At the begining of period 2, the government observes the realization of the default cost ϕ_I and then decides whether to default or not. Based on these assumptions, we can write the government's budget constrains as:

$$c_1 = y_1 + q\left(.\right) \times b$$

$$c_2 = \begin{cases} y_2 - b - B\left(1+\tilde{\pi}\right) & \text{if does not default} \\ y_2 - \phi_I & \text{if defaults} \end{cases}$$

where $q\left(.\right)$ represents the bond pricing kernel and it is defined below. A misreport on inflation has two immediate effects: it decreases the stock of inflation-indexed debt but it also partially reveals the government's type, which impacts on the price of non-indexed bonds. We now describe the problem of the two types of governments, starting from the last period backwards.

Period 2

Let $u(.)$ denote the government's utility function. At the beginning of the second period, after the default cost is realized, the impatient government chooses to default or not as to maximize that period's utility:

$$\max \left\{ u\left(y_2 - \phi_I\right), u\left(y_2 - b - B\left(1+\tilde{\pi}\right)\right) \right\} \tag{1}$$

Assuming that $u(.)$ is strictly increasing, the impatient government does not default if and only if $\phi_I \geq b + B\left(1+\tilde{\pi}\right)$. Thus $1 - G\left(b + B\left(1+\tilde{\pi}\right)\right)$ is the probability of no-default for the impatient government. Notice that this probability does not depend on the specific shape of the utility function, but only on the total stock of debt and the distribution of the default cost. Therefore, the information provided by m and the conjecture $\tilde{\Pi}_I^{\star}$ are sufficient for lenders to be able to price the government's debt. The pricing kernel is given by:

$$q\left(b, m; \tilde{\Pi}_I^{\star}\right) = \frac{1}{1+r}\left[\zeta' + (1-\zeta')\left[1 - G\left(b + B\left(1+\tilde{\Pi}_I^{\star}\right)\right)\right]\right] \tag{2}$$

Notice that the pricing kernel is increasing in the posterior ζ' and decreasing in the default probability. If lenders strongly believe that the government's is of the patient type, they will be willing to offer a higher price for the bond given that the patient type never defaults. Furthermore, there is an interactive effect between the government's reputation and the default probability. As the reputation ζ' falls, a greater weight is given to the default probability. In other words, for the same rise in the probability of default, the bond price will fall by more when reputation is low than when it is high. Alternatively, if the probability of default is small, $q(.)$ is almost invariant to changes in the posterior. This analysis implies that the impatient government has larger incentives to misreport in "good" economic times (low default probability) than in bad times (high default probability).

Period 1 - Stage 2

After the government chose $\tilde{\pi}$ and after the message m was realized, the government issues an exogenous amount of non-indexed bonds b. Given $\left(b, m; \tilde{\Pi}_I^{\star}\right)$ the value function for the patient type is given by:

$$\begin{aligned} W_P\left(b, m, \tilde{\pi} = 0; \tilde{\Pi}_I^{\star}\right) &= u\left(c_1\right) + \beta u\left(c_2\right) \\ \text{with} \quad c_1 &= y_1 + q\left(b, m, \tilde{\Pi}_I^{\star}\right) b \\ c_2 &= y_2 - b - B \end{aligned} \tag{3}$$

Similarly, given $\left(b, m, \tilde{\pi}; \tilde{\Pi}_I^{\star}\right)$, the value function for the impatient type is given by:

$$\begin{aligned} W_I\left(b, m, \tilde{\pi}; \tilde{\Pi}_I^{\star}\right) &= u\left(c_1\right) + \beta\left\{\int_{b+B(1+\tilde{\pi})}^{\bar{\phi}} u\left(c_2\right) dG\left(\phi_I\right) + \int_{\underline{\phi}}^{b+B(1+\tilde{\pi})} u\left(y_2 - \phi_I\right) dG\left(\phi_I\right)\right\} \\ \text{with} \quad c_1 &= y_1 + q\left(b, m, \tilde{\Pi}_I^{\star}\right) b \\ c_2 &= y_2 - b - B\left(1+\tilde{\pi}\right) \end{aligned} \tag{4}$$

Period 1 - Stage 1

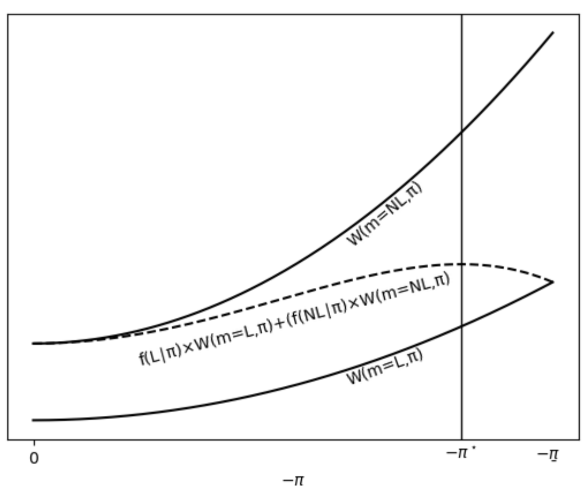
Let $P(m|\tilde{\pi})$ be the exogenous probability of receiving message m given the choice of the misreport. At the beginning of period 1, given the conjecture $\tilde{\Pi}_I^{\star}$, the impatient government solves the following optimal misreport problem:

$$\tilde{\pi_I}^* \left(\tilde{\Pi}_I^{\star}\right) = \arg\max_{\tilde{\pi}} \left\{ P(m = L|\tilde{\pi}) \times W_I \left(m = L, \tilde{\pi}, \tilde{\Pi}_I^{\star}\right) + P(m = NL|\tilde{\pi}) \times W_I \left(m = NL, \tilde{\pi}, \tilde{\Pi}_I^{\star}\right) \right\}$$
$$s.t. \quad \tilde{\pi} \in [\underline{\pi}, 0] \,, \underline{\pi} < 0 \tag{5}$$

where we impose a restriction to the maximum possible misreport ($\underline{\pi}$) to make sure that the default on indexed bonds is at most partial. In reality, a complete default may generate other costs for the government like output loses or sanctions from the international community.

Figure 2 provides a qualitative description of the problem on equation (5). On the one hand, conditional on a message m, the government benefits by increasing the underreport ($-\tilde{\pi}$) since it would have additional resources to consume in period 2. On the other hand, this would also lead to a rise in the probability of receiving message $m = L$. The latter imposes a cost to the government since the price of non-indexed bonds (weakly) decrease when $m = L$ is realized.[7]

FIGURE 2. Description of the Optimal Underreport



Having described the impatient government's problem, we now explain how beliefs are updated. Lenders observe a message m and update their belief about the government type using Bayes' rule. Regardless of the underreport, both messages have positive probability for any $\tilde{\pi}$, so Bayesian updating is well-behaved and there are no off-path information sets. Denote by

[7]This is why, for any given conjecture $\tilde{\Pi}_I^{\star}$, $W_I \left(m = NL, \tilde{\pi}; \tilde{\Pi}_I^{\star}\right) \geq W_I \left(m = L, \tilde{\pi}; \tilde{\Pi}_I^{\star}\right)$.

$l\left(m;\tilde{\Pi}_I^{\star}\right)$ the updated log likelihood ratio after message m is realized. Then lenders' update is given by

$$\begin{aligned} l\left(m;\tilde{\Pi}_I^{\star}\right) =& l_0 + \ln\frac{P\left(m|\tilde{\Pi}_P^{\star}=0\right)}{P\left(m|\tilde{\Pi}_I^{*}\right)} \\ \zeta'\left(m;\tilde{\Pi}_I^{\star}\right) =& \frac{exp\left\{l\left(m,\tilde{\Pi}_I^{\star}\right)\right\}}{1+exp\left\{l\left(m,\tilde{\Pi}_I^{\star}\right)\right\}} \end{aligned} \tag{6}$$

where l_0 is such that $\zeta = \frac{exp(l_0)}{1+exp(l_0)}$.

Definition **1.** *Perfect Bayesian Equilibrium - Two Period Economy*

Given an initial pair (ζ, B) and an exogenous bond policy b, a perfect Bayesian equilibrium (PBE) is a collection of value functions, $\{W_I(.), W_P(.)\}$ policy functions $\{\tilde{\pi}_I^{\star}(.)\}$, a conjecture about the impatient government's optimal misreport $\left\{\tilde{\Pi}_I^{\star}\right\}$, and a system of beliefs $\left\{\zeta'\left(m;\tilde{\Pi}_I^{\star}\right)\right\}$ such that:

(1) Given $\tilde{\Pi}_I^{\star}$, the posteriors $\zeta'\left(m;\tilde{\Pi}_I^{\star}\right)$ for $m \in \{L, NL\}$, are derived from equation (6).
(2) Given $\left(b, m, \tilde{\pi}; \tilde{\Pi}_I^{\star}\right)$, $W_j(.)$ is the associated value function for the j-type.
(3) Given the value function $W_I(.)$, $\tilde{\pi}_I^{\star}$ solves the problem in equation (5).
(4) The conjecture coincides with the optimal inflation policy: $\tilde{\Pi}_I^{\star} = \tilde{\pi}_I^{\star}$.

2.2. *Results*

In what follows we show a quantitative solution of the model under two cases: (i) perfect information and (ii) asymmetric information. In both cases we assume CRRA preferences given by $u(c) = \frac{c^{1-\gamma}}{1-\gamma}$. For the endowments, we assume $y_2 > y_1$ so that the government is willing to accumulate debt in the first period. Default costs are assumed to be $\phi_I \sim \mathcal{N}(A, \eta)$, where a lower A implies a lower average default cost and therefore a higher probability of default. Table 1 shows the parameters used when solving the model.

Table 1. Parametrization

Parameter	Description	Value
β	Discount factor	0.95
γ	Risk aversion	4.0
r	Risk-free rate	1%
y_1	Endowment at $t = 1$	0.8
y_2	Endowment at $t = 2$	1.3
A	Mean of default cost	0.7
η	S.d. of default cost	0.4
b	Issuances of non-indexed bonds	0.3
B	Stock of indexed bonds	$[0., 0.3]$
ζ	Lenders' prior	0.5
$\underline{\pi}$	Maximum misreport	-0.15
λ	Inverse of signal precision	0.1

Case 1: perfect information

This is the case where the government's inflation tampering is observable by international lenders. Under this scenario, $m = L$ whenever $\tilde{\pi} \neq 0$ and $m = NL$ only if $\tilde{\pi} = 0$ so that

$$P(m = L|\tilde{\pi}) = \begin{cases} 1 & \text{if } \tilde{\pi} \neq 0 \\ 0 & \text{if } \tilde{\pi} = 0 \end{cases}$$

Since Bayes' rule does not always apply under this scenario, we assume $\zeta' = 0$ for all the off-path information sets. Based on this assumption, we can summarize the update of beliefs as[8]

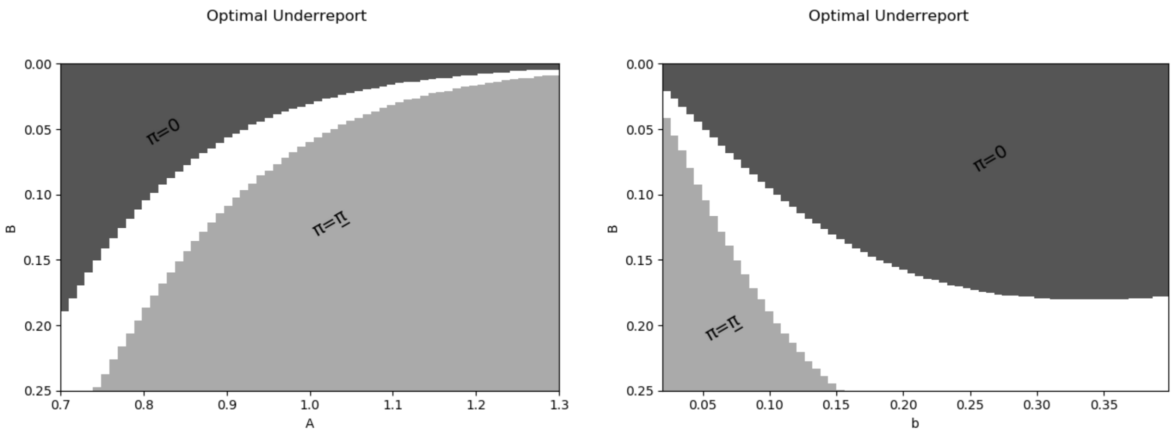
$$\zeta'\left(\tilde{\pi};\tilde{\Pi}_I^\star\right) = \begin{cases} \frac{\zeta}{\zeta+(1-\zeta)I_{\left\{\tilde{\Pi}_I^\star=0\right\}}} & \text{if } \tilde{\pi} = 0 \\ 0 & \text{if } \tilde{\pi} \neq 0 \end{cases}$$

Figure 3 shows the results, for different values of B, A, and b. There are only two possible equilibria, $\tilde{\pi} = 0$ and $\tilde{\pi} = \underline{\pi}$, since any $\tilde{\pi} \neq 0$ perfectly reveals the government type and the government's benefits are increasing in the underreport. The dark area represents those combinations of in which the optimal solution is to not underreport. The gray area represents

[8]As $\tilde{\pi}$ is observable, we define the Bayesian updating in terms of $\tilde{\pi}$, instead of m.

those combinations in which the sovereign finds optimal to set $\tilde{\pi} = \underline{\pi}$. The white area are combinations in which no equilibrium exists.

FIGURE 3. Optimal Misreport: Observable $\tilde{\pi}$ - Combinations of B, A, and b



(A) Inflation-linked debt and default cost (B) Inflation-linked and short-term debt

Notes: Results for the case in which the underreport is perfectly observable. Left panel shows results for different parametrizations of (B, A). Right panel shows results for different values of (B, b). The white area represents combinations in which no equilibrium exits.

The left panel of Figure 3 shows that the underreport is increasing in B and in A. The latter implies that the higher the impatient government's probability of default, the lower the incentives to misreport. When the probability of default is high, revealing its type affects significantly bond prices and therefore the impatient type has lower incentives to underreport. Overall, the government has more incentives to misreport in "good" times (low default probability) than in "bad" times (high default probability). The right panel of Figure 3 shows that the underreport is decreasing in b. This is because a higher b increases the default probability of the impatient type, leading to a larger drop in $q(.)$ if the government underreports inflation.

Within the white area, no equilibrium exists, given that the government always has incentives to deviate for any given $\tilde{\Pi}_I^\star$. The intuition behind this result is that there is a tension between the ("moderate") stock of indexed bonds and the probability of default. To see this, consider a point in this area such as $(B, A) = (0.15, 0.75)$ and assume that $\tilde{\Pi}_I^\star = \underline{\pi}$. In such case, due to the low A, the implied default probability is high and therefore the gains from deviating to $\tilde{\pi} = 0$ are significant (as this would imply a change in ζ' from 0 to 1 and significantly higher prices). On the other hand, if $\tilde{\Pi}_I^\star = 0$, part of the default probability is already incorporated into prices (given that $\zeta' = \zeta = 0.5$). This implies that the costs of revealing its type are smaller and the government finds optimal to deviate and set $\tilde{\pi} = \underline{\pi}$.

Case 2: asymmetric information

We now describe the results for the case in which $\tilde{\pi}$ is not observable. For simplicity, we assume a linear specification for the exogenous probability of receiving message m

$$P(x = L|\tilde{\pi}) = \frac{(1-\lambda)}{\underline{\pi}} \times \tilde{\pi} + \frac{\lambda}{2} \tag{7}$$

$$P(x = NL|\tilde{\pi}) = 1 - P(x = L|\tilde{\pi}) = -\frac{(1-\lambda)}{\underline{\pi}} \times \tilde{\pi} + \frac{2-\lambda}{2} \tag{8}$$

where $1/\lambda$ acts as the precision of the message; given $\tilde{\pi} < 0$, a lower λ implies that it is more likely to receive message $m = L$. Proposition 1 below states that in the absence of other costs of misreporting inflation the impatient government will always underreport.

Proposition 1. *(No Pooling Equilibrium) If $\tilde{\pi}$ is not perfectly observable by lenders, $\tilde{\pi} \neq 0$ for any $B > 0$.*

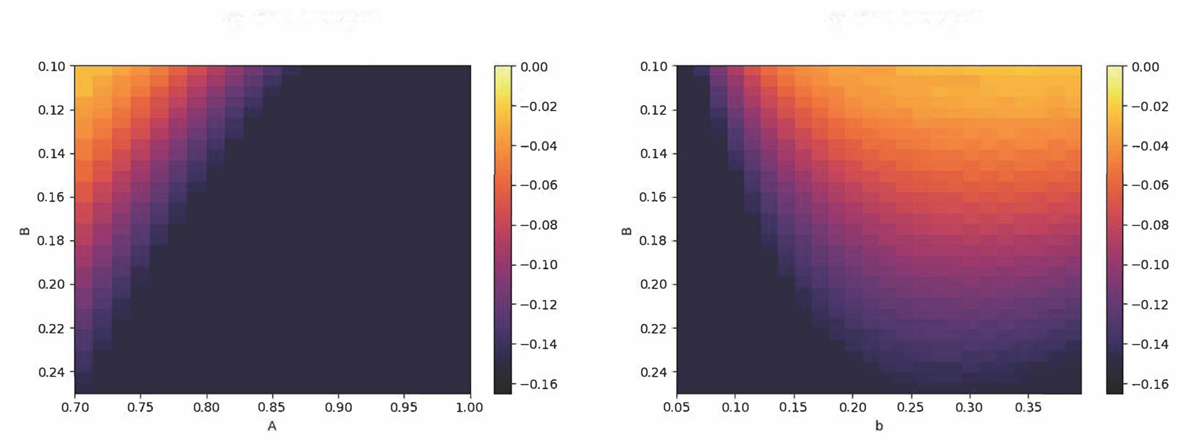
Proof. Conjecture that $\tilde{\pi} = 0$ is an equilibrium. In such a case, notice that $\zeta'\left(m; \tilde{\Pi}_I^\star = 0\right) = \zeta$, for any message m. Therefore, although the probability of receiving message $m = L$ is increasing in the underreport, any deviation from $\tilde{\pi} = 0$ will have no impact on lenders' beliefs. Thus, there is no cost to underreport inflation and the impatient government finds it optimal to set $\tilde{\pi} = \underline{\pi}$, a contradiction. □

A corollary from Proposition 1 is that no equilibrium exists for small values of B. The reason is that as $B \to 0$, the government's optimal misreport also converges to 0, as the benefits of misreporting are increasing in B. However, once $\tilde{\Pi}^\star = 0$, the government finds optimal to set $\tilde{\pi} = \underline{\pi}$, as explained in Proposition 1.

Figure 4 shows the results for different values of B, A, and b. Darker areas represent a higher underreport of inflation. Unlike the case where $\tilde{\pi}$ is perfectly observable, now there are no combinations of (B, A) and (B, b) for which no solution exists.[9] The intuition behind this is that adding noise to the signal of $\tilde{\pi}$ "convexifies" the government's problem. Compared to the case with perfect information, deviating from $\tilde{\Pi}_I^\star = 0$ to $\tilde{\pi} < 0$ is less costly for the government (as the misreport is not perfectly observable) but at the same time deviating from $\tilde{\Pi}_I^\star < 0$ to $\tilde{\pi} = 0$ is less profitable as lenders still assign positive probability to the event that the government is of the I-type.

[9] We assume $B > 0.1$ since no equilibrium exists for "small" values of B.

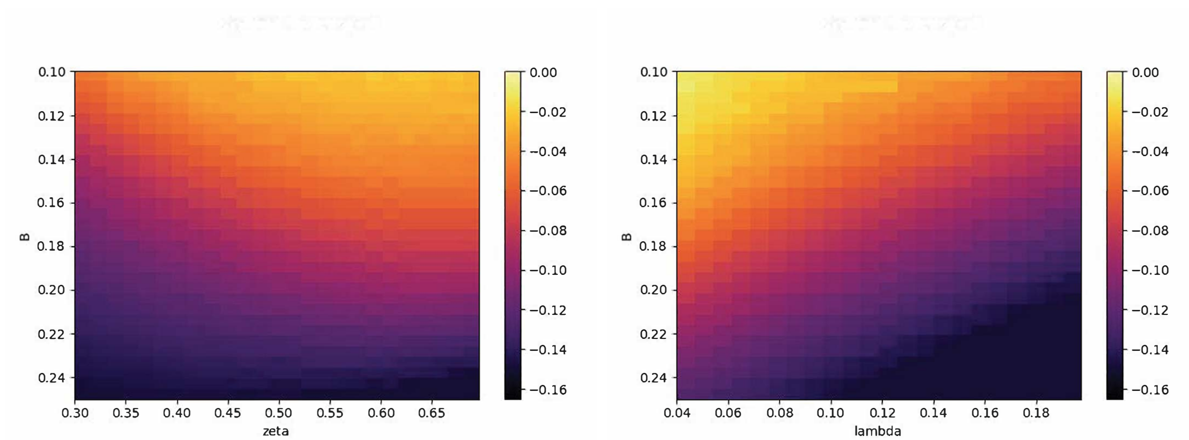
FIGURE 4. Optimal Misreport: Noisy Message- Combinations of B, A, and b



(A) Inflation-linked debt and default cost (B) Inflation-linked and nominal debt

Notes: Results for the case in which the underreport is not perfectly observable. Left panel shows results for different parametrizations of (B, A). Right panel shows results for different values of (B, b). Darker area represents a larger underreport of inflation.

FIGURE 5. Optimal Misreport: Noisy Message - Combinations of B, ζ, and λ



(A) Inflation-linked debt and lenders' prior (B) Inflation-linked and signal precision

Notes: Results for the case in which the underreport is not perfectly observable. Left panel shows results for different parametrizations of (B, ζ). Right panel shows results for different values of (B, λ). Darker area represents a larger underreport of inflation.

The left panel of Figure 4 shows that the magnitude of the underreport is increasing in B and in A. As in the perfect information case, when the probability of default is high, revealing the impatient type can significantly affect borrowing costs so that the impatient government has lower incentives to underreport. Similarly, the right panel shows that the underreport is decreasing in the stock of non-indexed bonds that the government will issue at the end of the first period (b), given that a higher b increases the default probability of the impatient type. Moreover, as noted in Proposition 1, note that $\tilde{\pi} \in (0, \underline{\pi}]$ for every combination of (B, A) and (B, b).

Figure 5 shows the results for different combinations of B, the prior ζ, and the precision of the signal λ. The left panel shows that given a value of B, the government's optimal underreport (weakly) increases as the prior decreases. In words, as lenders assign a worse reputation to the government, the costs of actually revealing the type become lower so the I-type government has stronger incentives to underreport. It is then clear that the government's actions are heavily influenced by the beliefs of market participants, a result that resembles the one in Cole and Kehoe (2000). The right panel of Figure 5 shows that as the precision of the signal increases (e.g., λ decreases) the underreport decreases. This is intuituve since, for a given value of $\tilde{\pi}$, a more precise signal improves lenders' update and therefore bond price sensitivity.

3. Case Study: Argentina's manipulation of the CPI Index

In this section, we analyze the effects of the Argentine government's misreport of inflation. Our goal is to estimate the effect of an increase in the (unexpected) misreport of inflation on Argentina's spread. We first start describing the episodes that characterized the tampering with the CPI, and show that Argentina's fundamentals around this time cannot explain the evolution of spreads. We then show the heteroskedasticity-based framework used, together with the results.

For the most part of the first half of the 2000s, the Argentine inflation rate was relatively low (at least for Argentina standards) but it peaked in 2005 to more than 10%.[10] The response of the government was to impose a series of price controls in 2006 as well as to pressure the staff to manipulate the computation of the price index elaborated by the National Statistics Institute (INDEC). In February 2007, the government directly intervened the INDEC and fired its higher rank members, including the statistician in charge of the CPI.[11] As shown on the left panel of figure 6, this triggered the creation of new private measures for the true value of inflation which we consider as noisy signals for market participants. The right panel shows that throughout the 2007-2012 period the government's inflation announcements were consistently lower than private measures. The magnitude of the underreport was significant and impacted heavily on the amount of inflation-indexed bonds (both coupons and principal) that the Argentine government had to pay. For instance, only considering the benefits in terms of lower coupon payments (i.e. without considering the effects on the principal) Argentina decreased its inflation-linked bonds payments from 2007 to 2010 by around $3.2 billion (around 1% of GDP).

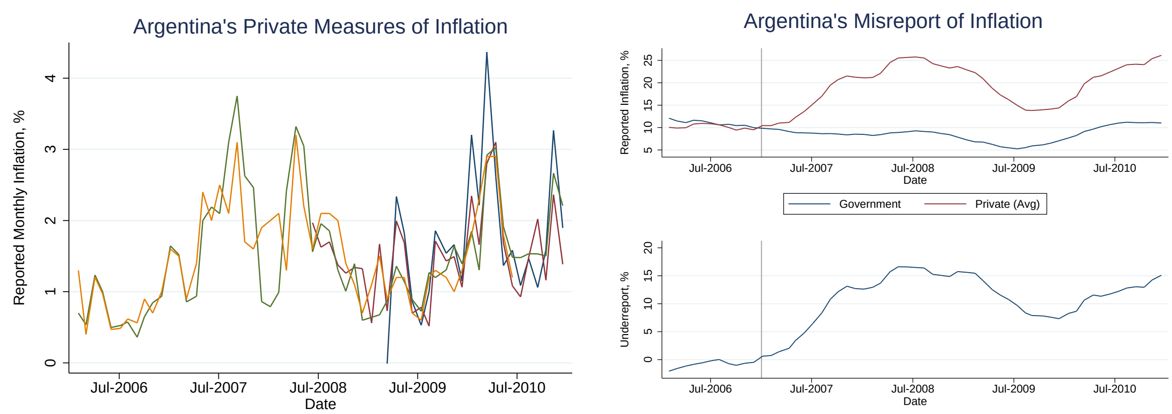
In what follows, we argue that the intervention of the INDEC and the consequent inflation tampering had an impact over Argentina's borrowing costs in international markets. Figure 7 presents the Emerging Markets Bond Index (EMBI) spreads for Argentina. During 2006, Argentine spreads were in line with that of other countries in the region. However, concurrently with the first misreport of inflation the Argentine spreads started to increase while the spreads for the other countries of the region remained fairly stable. In the next subsection, we first show that this decoupling cannot be explained by macroeconomic fundamentals nor by external factors. Our hypothesis is that the series of misreport on inflation significantly harmed

[10] The average annual inflation rate for 1984-2004 was 74% and the median was 11.4%. In contrast, the average annual inflation rate for 2000-2004 was 7.6% and the median was 3.5%.

[11] See Figure 1 in Cavallo et al. (2016) for a complete time-line of all the events from 2006 to 2015.

the government's reputation in international markets. We use a heteroskedasticity-based identification strategy to measure these short-run costs of losing reputation by focusing on windows around the government's inflation reports.

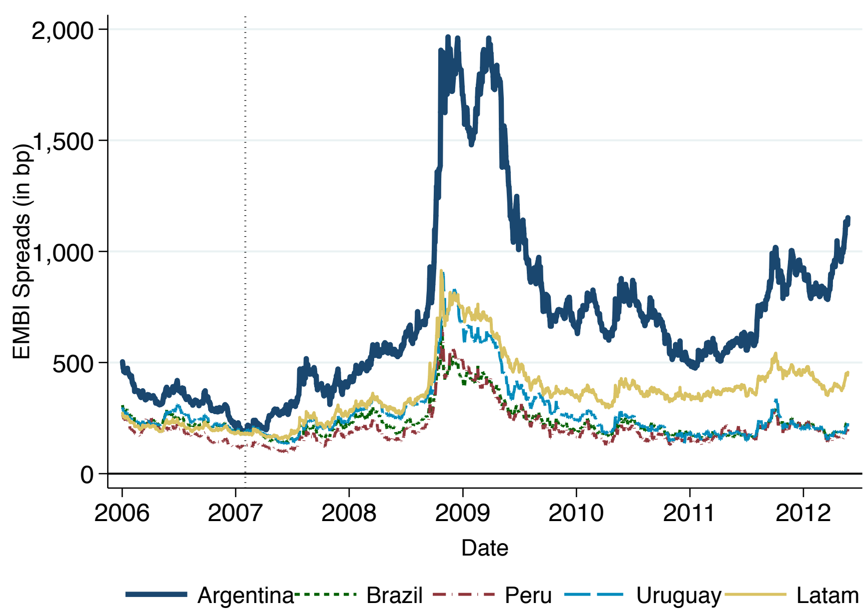
FIGURE 6. Argentina's Misreport of Inflation



(A) Argentina's private measures of inflation (B) Argentina's misreport of inflation

Notes:

FIGURE 7. Evolution of EMBI Spreads in Latin America



Notes:

3.1. *The Role of Fundamentals and External Factors*

This subsection analyzes whether a combination of Argentina's fundamentals and external factors can be behind the rise and decoupling on its spreads during 2007. A natural way to address this question would be to estimate the long-term relationship between Argentina's spreads, fundamentals (such as debt-to-GDP ratios and the GDP cycle) and external factors. Using that model, we could then test if there is a differential effect for 2007. However, such analysis would be hindered given that Argentina was in default prior to 2005 and also since the time series for fundamentals are in low frequency. Instead, we estimate a simple econometric model for a panel of 25 emerging countries (excluding Argentina) for 2003-2007 that links spreads to fundamentals and external factors. We then use those estimates and Argentina's fundamentals to predict Argentina's spreads for the 2006-2007 period.

The general specification for the panel regression is

$$SP_{it} = \beta_0 + \beta_1 \left(\frac{D}{Y}\right)^c_{i,t-1} + \beta_2 Y^c_{i,t-1} + \beta_3 I_i + \beta_4 \alpha_t + \Gamma \mathbf{X}_t + \epsilon_{it} \tag{9}$$

where i denotes a country and t a time period, $\frac{D_{it}}{Y_{it}}$ is a country's debt-to-GDP ratio, Y^c_{it} a county's real GDP cycle, I_i is country FE, α_t is time FE and $\mathbf{X}_t$ is a set of global control variables that might affect the behavior of international lenders.[12] These controls are the US real GDP cycle, the S&P500 index, the VIX, the MSCI Emerging Markets ETF (equity) index and the Fama-French three pricing factors (ER, SMB, and HML).[13] All variables are in percentage points.

[12]See data appendix for details on the sample. To avoid endogeneity we took lagged values of debt-to-GDP ratio and real GDP cycle. Debt-to-GDP ratios and GDP data are at quarterly frequency, while all other variables are at daily frequency. We let quarterly variables to take repeated values for each day in the quarter. Standard errors are Huber–White standard errors. Default periods are excluded.

[13]We include the Fama-French factors given that they are usually used in the finance literature to control for lender-side characteristics that may affect excess return of an asset. The implicit assumption on this regression is that the same lender that trades EM bonds, also trades US assets. ER refers to the market excess return, SMB denotes the the small-minus-big (size) portfolio factor, and HML is the high-minus-low book-to-market portfolio factor. Longstaff et al. (2011) and Morelli, Ottonello and Perez (2018) also use these three factors to explain sovereign spreads.

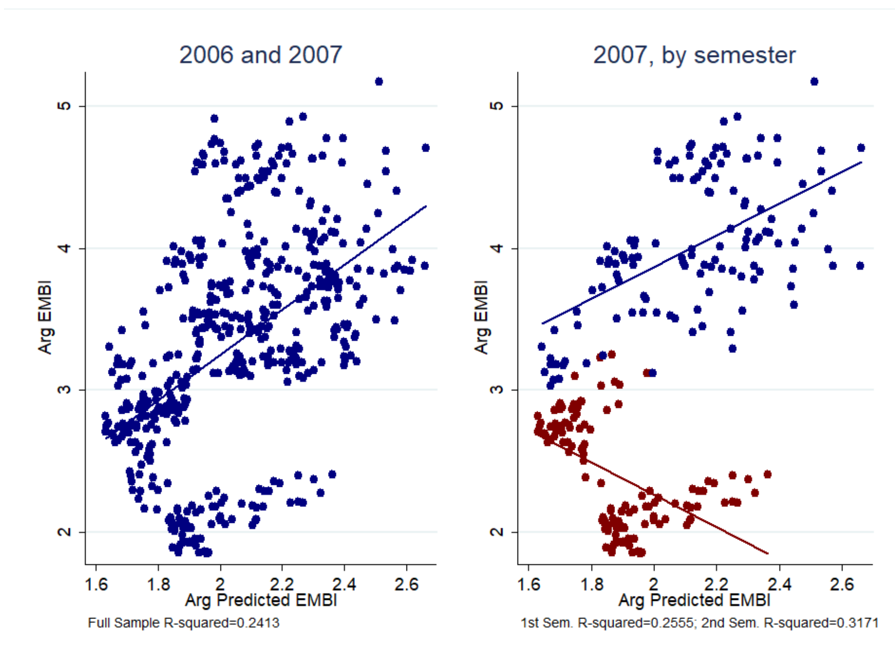
TABLE 2. Panel Regression 2003-2007 (Excluding Argentina)

	Dependent Variable SP_{it}					
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
$\left(\frac{D}{Y}\right)^c_{t-1}$	0.0294***	0.0307***	0.0294***	0.0047*	0.0145***	0.0046
	(0.0008)	(0.0008)	(0.0009)	(0.0028)	(0.0025)	(0.0029)
Y^c_{t-1}	-0.0549***	-0.0075***	-0.0548***	-0.0377***	-0.0107***	-0.0381***
	(0.0024)	(0.0021)	(0.0024)	(0.0034)	(0.0034)	(0.0034)
$Y^{c,US}_t$	-0.4484***	-0.4390***	-0.4513***	-0.3813***	-0.3215***	-0.3835***
	(0.0136)	(0.0236)	(0.0138)	(0.0069)	(0.0095)	(0.0071)
VIX		0.0354***			0.0459***	
		(0.0028)			(0.0013)	
SP		-0.0032***			-0.0018***	
		(0.0003)			(0.0001)	
EEM index		0.0177***			0.0302***	
		(0.0039)			(0.0019)	
ER			-0.0060			-0.0068
			(0.0115)			(0.0052)
SMB			-0.0055			-0.0119*
			(0.0183)			(0.0071)
HML			0.0091			-0.0194*
			(0.0291)			(0.0112)
Country-dummies	No	No	No	Yes	Yes	Yes
Country-trend dummies	No	No	No	Yes	Yes	Yes
No. of Countries	25	25	25	25	25	25
No. of Observations	23,682	18,805	22,853	23,682	18,805	22,853
R-squared	0.21	0.19	0.21	0.89	0.90	0.89

Table 2 shows the results of the panel regression which are in line with canonical models' of sovereign debt shows in the sense that higher debt-to-GDP ratios and depressed output are associated with higher spreads. Moreover, EM spreads heavily depend on global factors such as the US GDP, SP 500 index, and the VIX index. Fama-French factors do not affect significantly the spreads.

Next, we use Argentina's fundamentals and the regression estimates of Table 2 to forecast its spreads during 2006-2007. Figure 8 shows the relation between the observed Argentine spreads and the predicted ones (based on the results of column ii).[14] The left panel shows that for the 2006-2007 period, the estimated model does a reasonable job in estimating Argentina's spread as suggested by the positive correlation between actual and fitted spreads. However, the right panel shows that the correlation is actually negative during the first semester of 2007 (red dots), exactly when the government started misreporting the inflation rate. We take this as suggestive evidence that Argentina's international borrowing costs were reacting to something else, other than macroeconomic fundamentals or external factors.[15] In appendix C, we perform an additional exercise in which we consider EMs bonds as an international investors market and compute Argentine's bonds spread alpha against the market. We find a positive alpha during the first half of 2007, suggesting that investors penalize that particular asset as a result of the government's inflation tampering.

FIGURE 8. Argentine spreads: actual vs fitted



Notes: Argentina's EMBI was predicted using the results of regression (ii) in Table 2. The left panel shows the results for the 2006-2007 period. The 2003-2005 period is excluded as Argentina was in default. The right panel shows the results for 2007 only, separating by semester. Red (blue) dots correspond to the first (second) semester of 2007.

[14]Results are similar for the different specifications of Table 2 and are therefore omitted.

[15]Results are robust to including Argentina in the sample.

3.2. *Short-Run Effects of Inflation Tampering*

The objective on this section is to estimate the effect of an unexpected misreport of inflation on Argentina's spreads. We are interested in measuring the fraction of the government's misreport that was not priced by markets. However, there are some identification concerns. More precisely, it might have been the case that due to financial needs, the government misreported as a response to an initial rise in spreads. This concern motivates a simultaneous equation model. Let $\Delta R_t \equiv \frac{R_t - R_{t-1}}{R_{t-1}}$ denote the daily Argentine percentage change in EMBI spreads. Let $\tilde{\pi}$ be the government misreport of inflation (negative if underreport). Let $\tilde{\Pi}$ be the expectation that the market had about the government's misreport. Define $\tilde{\pi}^u \equiv \tilde{\pi} - \tilde{\Pi}$ as the unexpected misreport, where $\tilde{\pi}^u < 0$ means that the government underreported inflation more than what the market expected. Then, the simultaneous equation model can be specified as[16]

$$\Delta R_t = \alpha_0^\star + \alpha_1^\star F_t + \alpha_2^\star \tilde{\pi}_t^u + \epsilon_t^* \tag{10}$$

$$\tilde{\pi}_t^u = \beta_0^\star + \beta_1^\star F_t + \beta_2^\star \Delta R_t + \eta_t^* \tag{11}$$

Our goal is to estimate α_2, the effect of an increase in (unexpected) misreport of inflation on the EMBI spreads. If we simply run OLS in equation (10), there are two sources of bias: simultaneity and omitted variable bias. The former emerges if $\beta_2 \neq 0$. The latter exists if $\alpha_1 \neq 0$ and $\beta_1 \neq 0$. In order for the OLS estimate of α_2 to be unbiased, an exogenous change in EMBI spreads must have no effect on government's incentive to lie about inflation, and there must be no omitted common shocks. Of course, these two assumption are implausible in the Argentine context. To overcome these issues, we adopt a heteroskedasticity-based approach as suggested by Rigobon and Sack (2004). This methodology is described in the next section.

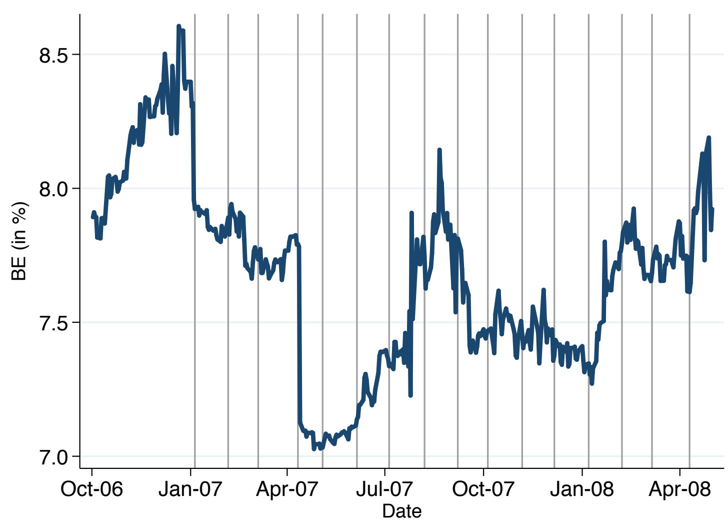
Another challenge for our empirical analysis is that the measure of unexpected misreport is not directly observable since there is no survey capturing market expectations about the official announcement of inflation. Instead, we proxy our variable of interest with changes in the break-even inflation rate (BE). This variable measures how much should inflation be for an investor to be indifferent between investing in nominal bonds or in inflation-indexed bonds. To

[16] Underlying this specification, it is the assumption that, to the extent that markets are efficient and competitive, if the market anticipated the misreport perfectly, then, on the announcement day, this misreport will not affect ΔR_t as this effect would have been already priced. In other words, only changes in $\tilde{\pi}_t^u$ should affect ΔR_t.

the extent that an unexpected underreport of inflation reduces the price of inflation-indexed bonds, we should expect BE to fall.[17]

We compute the BE inflation rate using the current yields of inflation-linked bonds and nominal bonds. A major set-back of the data is that there are only three nominal bonds in pesos being actively trading during the considered period. Moreover, there is only one bond for which we have yields data during 2007 and the first observation is only for July (six months after the government started misreporting inflation). To circumvent this issue, we use the yields of nominal bonds denominated in dollars adjusting their coupon with the expected depreciation rate of the peso. Appendix D describes the procedure used and figure 9 shows the times series of BE. Vertical lines indicate days in which the Argentine government reported the inflation rate, starting from Feb-07. On that first event of misreport we already observe a stark decline in the BE. The second large decrease was observed on April 11th, day in which an official rectification was issued regarding the last announcement (on April 4th). We substitute $\tilde{\pi}_t^u$ in equations 10 and 11 for $\Delta BE_t \equiv BE_t - BE_{t-1}$[18].

FIGURE 9. Break Even Inflation Rate



[17]The approach has the caveat that the yields of inflation-linked bonds may also reflect a liquidity component or an additional risk-premium, given that payoffs are stochastic (as opposed to nominal bonds). To the extent that this premium is constant across time, changes in the break-even inflation are a good proxy for the unexpected misreport of inflation.

[18]Notice that we do not use percentage change for the break-even inflation rate. BE_t is expressed in percentage points.

3.2.1. *Heteroskedasticity-based Identification Strategy*

In this section we estimate the effect of inflation misreport on Argentina's spreads. The sample is from Oct-06 to May-08. Although INDEC's intervention continued during the global financial crisis, we exclude this period from the analysis to avoid possible structural breaks. We classify observations into "events" (E) and "non-events" (NE). An event is defined as the 5-day windows around the date in which the government announced the inflation rate. For the set of non-event dates, we take the 5-days immediately after the last day of the event window. This way, we keep the samples the same size and minimizes any effects arising from changes in the variances of the shocks over time. We have 16 events in the considered sample period.[19] Table 3 reports some summary statistics.

TABLE 3. Summary Statistics

Window Type	Event	Non-Event
Mean ΔR_t	0.00535	0.00063
SD ΔR_t	0.03352	0.03258
Mean ΔBE_t (percent)	-0.00634	0.00192
SD ΔBE_t	0.10373	0.08944
Cov($\Delta R_t, \Delta BE_t$)	-0.00051	0.00069
Observations	92	321

Notes: Event days are defined as 5-days windows around the date in which the government announced the inflation rate.

To estimate the effect that changes in the break-even inflation rate has on EMBI spreads we follow the heteroskedasticity-based approach of Rigobon and Sack (2004). The identifying assumption is that the variance of shocks to BE (η) is higher on event days than on non-event days, while the variances of the common shocks (F) and spread shocks (ϵ) remain invariant. To observe the implication of this assumption, we rewrite the system of simultaneous equations (10)-(11) in reduced-form as:

[19]See Appendix E for a list of the events.

$$\Delta R_t = \frac{\alpha_0 + \alpha_2\beta_0 + [\alpha_1 + \alpha_2\beta_1] F_t + \alpha_2\eta_t + \epsilon_t}{1 - \alpha_2\beta_2}$$
$$\Delta BE_t = \frac{\beta_0 + \beta_2\alpha_0 + [\beta_1 + \beta_2\alpha_1] F_t + \beta_2\epsilon_t + \eta_t}{1 - \alpha_2\beta_2}$$

Our object of interest is the variance-covariance matrix Φ_j between the two observables (ΔR_t, ΔBE_t), for each $j = \{E, N\}$. The reduced-form system of equations implies that

$$\Phi_j = \left(\frac{1}{1-\alpha_2\beta_2}\right)^2 \begin{bmatrix} (\alpha_1+\alpha_2\beta_1)^2 \sigma_F^2 + \alpha_2^2\sigma_{\eta,j}^2 + \sigma_\epsilon^2 & [\alpha_1+\alpha_2\beta_1][\beta_1+\beta_2\alpha_1]\sigma_F^2 + \alpha_2\sigma_{\eta,j}^2 + \beta_2\sigma_\epsilon^2 \\ [\alpha_1+\alpha_2\beta_1][\beta_1+\beta_2\alpha_1]\sigma_F^2 + \alpha_2\sigma_{\eta,j}^2 + \beta_2\sigma_\epsilon^2 & (\beta_1+\beta_2\alpha_1)^2\sigma_F^2 + \beta_2^2\sigma_\epsilon + \sigma_{\eta,j}^2 \end{bmatrix}$$

By defining $\Delta\Phi = \Phi_E - \Phi_{NE}$ we get

$$\Delta\Phi = \left(\frac{1}{1-\alpha_2\beta_2}\right)^2 \left[\sigma_{\eta,E}^2 - \sigma_{\eta,NE}^2\right] \begin{bmatrix} \alpha_2^2 & \alpha_2 \\ \alpha_2^2 & 1 \end{bmatrix}$$

This provides a way of estimating the parameter of interest α_2. We will use the same estimator employed by Hebert and Schreger (2017), given by:

$$\hat{\alpha}_{2-IV} = \frac{\Delta\Phi_{1,2}}{\Delta\Phi_{2,2}}$$

As shown by Rigobon and Sack (2004), this estimator can be implemented in an instrumental variables framework. This IV instrument is relevant only under the assumption that $\sigma_{\eta,E}^2 - \sigma_{\eta,NE}^2 > 0$. We test if this assumption holds using a one-sided F-test of $\sigma_{\Delta BE,E}^2/\sigma_{\Delta BE,NE}^2$. For our sample, we can reject the null at the 1%.

Table 4 shows the result of the IV estimator. It indicates that a 1 percentage point decrease (say, from 8% to 7%) in the BE inflation rate (i.e, an increase in the perceived lie about the inflation rate) leads to a 14% increase in the Argentine EMBI spread. These results are similar to the ones obtained in an event study analysis carried out in appendix G.

Table 4. Heteroskedasticity IV

Dependent Variable: $\Delta R_t = \frac{R_t - R_{t-1}}{R_{t-1}}$		
	(i)	(ii)
$\Delta BE_t = BE_t - BE_{t-1}$	-0.1445^{***}	-0.1274^{***}
Standard Error	0.0581	0.0341
95 percent CI	$[-0.197, -0.038]$	$[-0.180, -0.047]$
Global Controls	No	Yes
Number of Events	17	17
Observations	181	174

Notes: Table reports the results for the heteroskedasticity IV estimator. Standard errors correspond to the heteroskedasticity-robust standard error. Confidence intervals are computed using the stratified bootstrap procedure, described in Appendix F. Significance level: *** $p < 0.01$. The underlying data is based on the 5-day event and non-events windows. Column (ii) describes the results when controlling for changes in global factors: VIX index, the S&P 500 index the MSCI Emerging Markets ETF index, and Asia's EMBI.

4. The Infinite Horizon Economy

We now consider the infinite horizon version of the model. In this case the government can issue long-term non-contingent bonds (b) and it also faces a legacy stock of inflation-indexed bonds (B). For simplicity, we assume that inflation-indexed bonds are perpetuities, so that each period an amount B of inflation-indexed bond coupons matures. We maintain our assumption that the patient government never misreports inflation, but we now assume that it can default. We make the standard assumption that the stock of non-indexed debt is zero after exiting a default. Moreover, to avoid the complications derived from the potential existence of multiple equilibria (see Appendix B) we maintain the assumption that bond policies are uninformative about the government's type.

We assume that the endowment evolves stochastically according to a Markov chain with transition matrix T_y. We also assume that the type of government evolves stochastically according to a Markov chain with transition matrix T. Following Chatterjee and Eyigungor (2012), we consider long-term debt contracts that mature probabilistically. In particular, a unit of non-indexed bonds matures next period with probability m_b. If the non-indexed bond does not mature and the government does not default, it gives a coupon payment of z_b. Based on these assumptions, if the country is not currently in default its resource constraint is given by:

$$c = y - b\left[(1-m_b)\,z_b + m_b)\right] + q\,(.)\,[b' - (1-m_b)b] - B\,(1+\tilde{\pi})$$

where $q(.)$ is the pricing kernel of non-indexed bonds, c is today's consumption and $\tilde{\pi}$ is the misreport of inflation.

Timing of Events

FIGURE 10. Timing of Events: Infinite-period model

		If no default:	
Government starts with $\mathbf{S} = (y, b, \zeta)$. Lenders conjecture are: $\tilde{\Pi}(\mathbf{S})$.	The (impatient) government chooses to default or not.	Stage 1: Government chooses $\tilde{\pi}$, and message $m = \{L, NL\}$ is realized. Lenders update their posterior.	Stage 2: Government chooses b'.

Let ζ denote the lender's prior about the government being P-type. Let $\mathbf{S} = (y, b, \zeta)$ be the state at the beginning of the period. Let $\tilde{\Pi}_I^{\star} = \tilde{\Pi}(\mathbf{S})$ be the lenders' expectation about the impatient government's misreport of inflation. Assuming that the government is not currently in default, the timing of events is as follows (see figure 10):

(1) At the beginning of the period, government chooses to default ($d = 1$) or not.
(2) If government defaults:
    (a) It is temporary excluded from international market and regains access with probability θ next period.
    (b) Faces output cost $\phi^j(y)$, for $j = \{P, I\}$. We assume that $\phi^P(y) \geq \phi^I(y)$ for all y, meaning that the impatient government faces (weakly) larger incentives to default.[20]
(3) If government does not default, the period is divided into two stages:

[20]In Alfaro and Kanczuk (2005) and D'Erasmo (2011), the patient type differs from the impatient type in the discount factor parameter β. Our specification of different default costs is similar to that in Barret (2016).

(a) At stage 1, the impatient government chooses the report on inflation ($\tilde{\pi}$). A message the message $m \in \{L, NL\}$ is realized based on $\tilde{\pi}$.

(b) Lenders update their posterior ζ' using m and $\tilde{\Pi}(\mathbf{S})$.

(c) At stage 2, the government chooses b' given some price schedule $q(y, b', \zeta')$.

Update of Beliefs

Beliefs about the government's type are updated tiwce within a period: after the default decision and after the message m is realized. We start describing the update of beliefs for the former case. Let $d_j^\star = d_j(\mathbf{S})$ be the lenders' expectation about the j-type government's default decision (given the current state $\mathbf{S}$). Let $d = \{0, 1\}$ be the actual default choice and let $\tilde{\zeta}$ be the updated posterior after observing d. Then[21]

$$\tilde{\zeta}(d; \zeta, d_I^\star, d_P^\star) = \frac{Prob(d \mid d_P^\star) \times \zeta}{Prob(d \mid d_P^\star) \times \zeta + Prob(d \mid d_I^\star) \times (1 - \zeta)} \tag{12}$$

As in the 2-period model, lenders observe a message m and update their log likelihood ratio using Bayes' rule. Regardless of the underreport, both messages have positive probability so Bayes' rule always applies and there are no off-path information sets. To ease notation, let $\tilde{\Pi}_I^* \equiv \tilde{\Pi}(\mathbf{S})$ be the lender's expectation about the I-type misreport of inflation. After observing m, the updated posterior $\Sigma\left(m; \tilde{\Pi}_I^*\right)$ is given by

$$\Sigma\left(m; \tilde{\zeta}, \tilde{\Pi}_I^*\right) = \frac{Prob(m \mid 0) \times \tilde{\zeta}}{Prob(m \mid 0) \times \tilde{\zeta} + Prob(m \mid \tilde{\Pi}_I^*) \times \left(1 - \tilde{\zeta}\right)} \tag{13}$$

Let T_{ij} be the element (i, j) of the government's type transition matrix. The law of motion for the posterior is given by

$$\zeta'\left(m; \tilde{\zeta}, \tilde{\Pi}_I^\star\right) = T_{PP}\Sigma\left(m; \tilde{\zeta}, \tilde{\Pi}_I^\star\right) + T_{IP}\left[1 - \Sigma\left(m; \tilde{\zeta}, \tilde{\Pi}_I^\star\right)\right] \tag{14}$$

In what follows, we describe the problems of the patient and impatient governments.

[21]For off-equilibrium paths, we simply assume that $\tilde{\zeta}(d; \zeta, d_I^\star, d_P^\star) = 0$.

Stage 2: Bond Policy

At this stage, the impatient government takes the state $(m, \tilde{\pi}, y, b, \tilde{\zeta})$ as given, as well as the market's expectation about the misreport $\tilde{\Pi}_I^\star$ and (future) default decisions. Then, the debt issuance problem is given by[22]

$$\begin{aligned} V^I\left(m, \tilde{\pi}, y, b, \tilde{\zeta}\right) = \max_b u\left(c\right) + \beta \int_y \Big\{ T_{II} W^I\left(y', b', \zeta'\right) + T_{IP} W^P\left(y', b', \zeta'\right) \Big\} dF\left(y' \mid y\right) \\ s.t. \quad y - b\left[\left(1 - m_b\right) z_b + m_b\right)\right] + q\left(y, b'\zeta'\right)\left[b' - (1 - m_b) b\right] - B\left(1 + \tilde{\pi}\right) \\ \zeta' \equiv \zeta'\left(m; \tilde{\zeta}, \tilde{\Pi}_I^\star\right) \\ \tilde{\Pi}_I^\star \equiv \tilde{\Pi}\left(\mathbf{S}\right) \end{aligned} \tag{15}$$

For the patient type, the bond issuance problem is given by

$$\begin{aligned} V^P\left(m, y, b, \tilde{\zeta}\right) = \max_{b'} u\left(c\right) + \beta \int_y \Big\{ T_{PP} W^P\left(y', b', \zeta'\right) + T_{PI} W^I\left(y', b', \zeta'\right) \Big\} dF\left(y' \mid y\right) \\ s.t. \quad c = y - b\left[\left(1 - m_b\right) z_b + m_b\right)\right] + q\left(y, b'\zeta'\right)\left[b' - (1 - m_b) b\right] - B \\ \zeta' \equiv \zeta'\left(m; \tilde{\zeta}, \tilde{\Pi}_I^\star\right) \\ \tilde{\Pi}_I^\star \equiv \tilde{\Pi}\left(\mathbf{S}\right) \end{aligned} \tag{16}$$

Stage 1: Inflation Misreport Policy

For the impatient type, the choice of misreport on inflation solves:

$$\begin{aligned} W_R^I\left(y, b, \zeta\right) = \max_{\tilde{\pi}} \Big\{ P(m = L|\tilde{\pi}) \times V^I\left(m = L, \tilde{\pi}, y, b, \tilde{\zeta}\right) + \\ + P(m = NL|\tilde{\pi}) \times V^I\left(m = NL, \tilde{\pi}, y, b, \tilde{\zeta}\right) \Big\} \\ s.t. \quad \tilde{\pi} \in [\underline{\pi}, 0] \\ \text{with} \quad \tilde{\zeta} = \tilde{\zeta}\left(d = 0; \zeta, d_I^\star, d_P^\star\right) \end{aligned} \tag{17}$$

As the patient type never misreports, we can define:

$$\begin{aligned} W_R^P\left(y, b, \zeta\right) = P(m = L|\tilde{\pi} = 0) \times V^P\left(m = L, y, b, \tilde{\zeta}\right) + \\ + P(m = NL|\tilde{\pi} = 0) \times V^P\left(m = NL, y, b, \tilde{\zeta}\right) \\ \text{with} \quad \tilde{\zeta} = \tilde{\zeta}\left(d = 0; \zeta, d_I^\star, d_P^\star\right) \end{aligned} \tag{18}$$

[22]To avoid cumbersome notation, we avoid writing $\tilde{\Pi}_I^\star$ and the expected default decision as inputs of the value functions.

Beginning of period: Default Decision

If the type j- government is currently out of default, its default decision solves:

$$W^j(y,b,\zeta) = Max_{d\in(0,1)}\left\{W_R^j(y,b,\zeta),\, W_D^j(y,b,\zeta)\right\} \tag{19}$$

where W_R^j is defined in equations (17-18) and W_D^j, for $j=\{P,I\}$ is given by:

$$\begin{aligned} W_D^j(y,b,\zeta) =& u\left(y-\phi^j(y)\right)+ \\ &+\theta\beta\int_y\left\{T_{jj}W^j(y',0,\zeta')+T_{j(-j)}W^{(-j)}(y',0,\zeta')\right\}dF(y'\mid y) \\ &+[1-\theta]\beta\int_y\left\{T_{jj}Q_D^j(y',b,\zeta')+T_{j(-j)}Q_D^{(-j)}(y',b,\zeta')\right\}dF(y'\mid y) \end{aligned} \tag{20}$$

$$s.t.\quad \zeta' = T_{PP}\tilde{\zeta}(d=1;\zeta,d_I^\star,d_P^\star)+T_{IP}\left[1-\tilde{\zeta}(d=1;\zeta,d_I^\star,d_P^\star)\right]$$

Finally, if the government is already in default, we have that:

$$\begin{aligned} Q_D^j(y,b,\zeta) =& u\left(y-\phi^j(y)\right)+ \\ &+\theta\beta\int_y\left\{T_{jj}W^j(y',0,\zeta')+T_{j(-j)}W^{(-j)}(y',0,\zeta')\right\}dF(y'\mid y) \\ &+[1-\theta]\beta\int_y\left\{T_{jj}Q_D^j(y',b,\zeta')+T_{j(-j)}Q_D^{(-j)}(y',b,\zeta')\right\}dF(y'\mid y) \end{aligned} \tag{21}$$

$$s.t.\quad \zeta' = T_{PP}\zeta+T_{IP}[1-\zeta]$$

Notice that the only difference between (20) and (21) is the evolution of the posterior, given that in the latter expression it evolves exogenously, while in the former it depends on the default choice.

Pricing Kernels

Let $\zeta' \equiv \zeta'\left(m; \tilde{\zeta}, \tilde{\Pi}_I^\star\right)$ be the updated posterior, after observing message m (and the default decisions). The pricing kernel is given by:

$$
\begin{aligned}
& q\left(y, b', \zeta'\right) = \\
& \quad \frac{\zeta'}{1+r} \int \Big\{ \left(1 - d_P(y', b', \zeta')\right) \times \Big[Prob(m = L \mid 0) \left\{ m_b + (1 - m_b)\left(z_b + q'_{P,L}\right) \right\} \\
& \qquad + Prob\left(m = NL \mid 0\right) \left\{ m_b + (1 - m_b)\left(z_b + q'_{P,NL}\right) \right\} \Big] \Big\} dF\left(y' \mid y\right) \\
& + \frac{(1-\zeta')}{1+r} \int \Big\{ \left(1 - d_I(y', b', \zeta')\right) \times \Big[Prob(m = L \mid \tilde{\Pi}_I^\star) \left\{ m_b + (1 - m_b)\left(z_b + q'_{I,L}\right) \right\} \\
& \qquad + Prob(m = NL \mid \tilde{\Pi}_I^\star) \left\{ m_b + (1 - m_b)\left(z_b + q'_{I,NL}\right) \right\} \Big] \Big\} dF\left(y' \mid y\right)
\end{aligned}
\tag{22}
$$

where q'_{jm} is tomorrow's price of non-indexed bonds, given that the government is of type j, it did not default, and message m was realized. Formally, for each type j and message m, we have that:

$$
\begin{aligned}
q'_{jm} &= q_{j,m}\left(y', b'', \zeta''\right) \\
&= q\left(y', b'_j\left(m, \tilde{\Pi}_j^\star, y', b', \tilde{\zeta}'\right), \zeta''\right) \\
\zeta'' &= \zeta'\left(m; \tilde{\zeta}', \tilde{\Pi}_I^\star\right) \\
\tilde{\zeta}' &= \tilde{\zeta}\left(d = 0; \zeta', d_I^\star, d_P^\star\right) \\
d_j^\star &= d_j^\star(y', b', \zeta') \\
\tilde{\Pi}_j^\star &= \tilde{\Pi}_j^\star\left(y', b', \tilde{\zeta}'\right)
\end{aligned}
$$

With short-term debt (i.e., $m_b = 1$) the pricing kernel collapses to

$$
q\left(y, b', \zeta'\right) = \frac{1}{1+r} \int \Big\{ \zeta'\left(1 - d_P(y', b', \zeta')\right) + \left(1 - \zeta'\right)\left(1 - d_I(y', b', \zeta')\right) \Big\} dF\left(y' \mid y\right) \tag{23}
$$

When comparing this expression to 22, we observe that reputation ζ' now affects only *future prices*. This implies that, for reasonable parameters of the model, the reputational costs of misreporting inflation are "too small" so the impatient government finds it optimal to set the maximum value of misreport (i.e., $\tilde{\pi} = \underline{\pi}$). This is not the case with long-term debt, since a loss in reputation can have a significant impact on bond prices, even when the default probability is low.

Definition **2.** *Perfect Bayesian Equilibrium - Inifinite Horizon Economy*

A PBE is a collection of value functions, $\left\{W^j(.), W_R^j(.), W_D^j, V^j\right\}_{j=\{1,2\}}$*, bond and default policy functions* $\{b_j(.),\, d_j(.),\}_{j=\{1,2\}}$*, misreport policy for the impatient type* $\tilde{\pi}_I(.)$*, lenders' conjectures*$\left\{\tilde{\Pi}_I^*(.)\,, d_I^\star(.)\,, d_P^\star(.)\right\}$*, and lenders' system of beliefs* $\left\{\zeta'(.)\,, \tilde{\zeta}(.)\right\}$ *such that:*

1. *Given* $(d_I^\star(.)\,, d_P^\star(.))$*, the posterior* $\tilde{\zeta}(d; \zeta, d_I^\star, d_P^\star)$*, for* $d \in \{0,1\}$*, is derived from equation (12).*
2. *Given* $\tilde{\Pi}_I^\star(.)$*, the posterior* $\zeta'\left(m; \tilde{\zeta}, \tilde{\Pi}_I^\star\right)$*, for* $m = \{NL, L\}$*, is derived from equation (14).*
3. *Given* $\left(m, \tilde{\pi}, y, b, \tilde{\zeta}\right)$ *and* $\tilde{\Pi}_I^*$*,* $b_I(.)$ *solves the impatient government's problem in equation (15) and* $V^I(.)$ *is the associated value function. Similarly, for the patient government, given* $\left(m, \tilde{\pi} = 0, y, b, \tilde{\zeta}\right)$*,* $b_P(.)$ *solves the problem in equation (16) and* $V^P(.)$ *is the associated value function.*
4. *Given the value function* $V^I(.)$*,* $\tilde{\pi}_I$ *solves the problem in equation (17) and* $W_R^I(.)$ *is the associated value function. For the patient type, as he faces commitment,* $\tilde{\pi} = 0$ *and* $W_R^P(.)$ *is the associated value function.*
5. *For each* $j = \{P, I\}$*, given* $W_D^j(.)$ *(defined in equation 20) and* $W_R^j(.)$*,* $d_j(.)$ *solves the problem in equation 19, and* $W^j(.)$ *is the associated value function.*
6. *Lenders conjecture coincide with optimal policies. That is (for each point of the space state),* $\tilde{\Pi}_I^*(.) = \tilde{\pi}_I(.)$*,* $d_I^\star(.) = d_I(.)$ *and* $d_P^\star(.) = d_P(.)$*.*

4.1. *Calibration*

To be consistent with the empirical analysis, we use Argentinean data to calibrate the model. We have a set of 13 parameters to be calibrated; a subset of those are taken from previous literature and the rest are chosen to match some moments. In our model a period is a quarter.

Before describing the targeted moments, we define some remaining functions that are necessary to quantitatively solve the model. As it is standard in the sovereign debt literature, the consumer has a CRRA utility function

$$u(c) = \frac{c^{1-\gamma}}{1-\gamma} \tag{24}$$

with risk aversion parameter γ. We also assume the endowment process follows an AR(1) in logs as given by

$$log\,(y_t) = \rho\, log\,(y_{t-1}) + \epsilon_t;\ \epsilon_t \sim N(0, \sigma)$$

We model the exogenous default costs on income as

$$\phi_j(y) = max\left\{\left(\bar{\chi_0} + \chi_j\right)y + \bar{\chi_1}y^2, 0\right\} \tag{25}$$

where $j = \{I, P\}$, $\bar{\chi_0} < 0$ and $\bar{\chi_1} > 0$. We set $0 > \chi_I = -\chi_P$ in order to get a larger default set for the impatient type. In this version of the model, annualized spread is given by[23]

$$Spread_b = \left(\frac{1 + r_b\left(y, b', \zeta'\right)}{1 + r}\right)^4 - 1 \tag{26}$$

where $r_b\left(y, b', \zeta'\right)$ is the internal rate of return as defined by

$$q\left(y, b', \zeta'\right) = \frac{\left[m_b + \left(1 - m_b\right)z_b\right]}{m_b + r_b\left(y, b', \zeta'\right)} \tag{27}$$

The last function we need to specify is the probability of receiving message $m = L$, which we assume takes a non-linear specification

$$P\left(m = L \mid \tilde{\pi}\right) = \alpha_0 + c \times \tilde{\pi}^{\alpha_1} \tag{28}$$

The set of parameters that we take as standard from the literature is $\{\gamma, r, \theta\}$. We set the risk aversion $\gamma = 2$. The real rate is set to $r = 1\%$, in line with the observed average real rate in the United States. The re-entry parameter is set to $\theta = 0.0385$, implying an average exclusion period from international markets after a default of 6.5 years.[24]

The set of calibrated parameters is $\{\rho, \sigma, m_b, z_b, \beta, \chi_0, \chi_1, B, \alpha_0, c, \alpha_1, \chi_I\}$. The parameters for the endowment process are $\rho = 0.948$ and $\sigma = 0.027$, as taken from Chatterjee and Eyigungor (2012) for the period 1993q1 to 2001q4. We also set $m_b = 0.05$ to match an average debt maturity of 5 years and $z_b = 0.03$ to match the debt service. The parameters (β, χ_0, χ_1) are chosen to match: (i) an average ratio of external debt (both indexed and non indexed) over (quarterly) GDP of 70%;[25] (ii) an average sovereign spread of 7.5%; (iii) an average volatility of sovereign spreads of 4.5%. Another parameter to calibrate is the stock of inflation-indexed bonds. Since these are not actually perpetuities in the data, we instead chose B to match the

[23]Notice that if there is no possibility of default, the unit price of a non-indexed bond satisfies: $\bar{q} = \frac{m_b + (1-m_b)[z_b + \bar{q}]}{1+r}$, which in turn implies that: $\bar{q} = \frac{[m_b + (1-m_b)z_b]}{m_b + r}$. As $q\left(y, b', \zeta'\right) \leq \bar{q}$, it follows that $r_b\left(y, b', \zeta'\right) \geq r$, with strict inequality if for $\left(y, b', \zeta'\right)$ the probability of default is not zero.

[24]This measure is taken from Chatterjee and Eyigungor (2012) and it is constructed as an average of the time it took to Argentina to reach settlement on the defaulted debt in different default episodes, based on data provided by Beim and Calomiris (2000); Benjamin and Wright (2009); and Gelos et al. (2011).

[25]We match only a portion of debt because we do not model repayment. In Argentina's case, the repayment on debt defaulted has been around 30%.

Table 5. Calibration of the Model

Description	Parameter	Value	Targeted Moment / Source
Risk-free rate	r	0.01	Standard Values
Risk Aversion	γ	2	Standard Values
Income Autocorrelation	ρ	0.948503	Chatterjee and Eyigungor (2012)
Standard deviation of Innovations	σ	0.027092	Chatterjee and Eyigungor (2012)
Discount Factor	β	0.97	Spreads and Stock of Debt
Income Cost of Defaulting	$\bar{\chi}_0$	-0.18	Spreads and Stock of Debt
Income Cost of Defaulting	$\bar{\chi}_1$	0.24558	Spreads and Stock of Debt
Probability of Reentering Markets	θ	0.0385	Duration of Default - 6.5 years
Maturity of Debt	m_b	0.05	Average Maturity - 5 years
Coupon Payments of Non-indexed Debt	z_b	0.03	Debt Services
Indexed debt services	B	0.0137	Debt Services of IIBs
$P\left(m=L \mid \tilde{\pi}\right)$	α_1	3	See text
Default Cost Difference	(χ_I, χ_P)	$(-0.005, 0.005)$	See text

average debt services of inflation-linked bonds as a share of the total debt services (around 25 percent in 2007).

Using the results of Section 3, we calibrate the probability of detecting the underreport, $P\left(m=L \mid \tilde{\pi}\right)$, as well as the default cost difference parameters χ_j in order to match the short-term increase in Argentine spreads caused by the misreport. Parameters α_0 and c in equation 28 are chosen so that $P\left(m=L \mid \tilde{\pi}=\underline{\pi}\right)=100\%$ and $P\left(m=L \mid \tilde{\pi}=0\right)=5\%$, with $\underline{\pi}=-3\%$.[26] The parameter α_1 is calibrated to approximate the probability that message $m=L$ is realized, given that the government is of the $I-type$. During 2007, the market detected misreports around 16% of the times, so we set $\alpha_1=3$ to roughly match this value. The cubic specification ensures that the probability of detecting a misreport is very low if $\tilde{\pi}$ is close to zero, but increases fast as the underreport increases. Finally, we set the default costs $0>\chi_I=-\chi_P$ to ensure that the impatient type has larger incentives to default (due to the lower default cost). We set

[26] If we set $P\left(m=L \mid \tilde{\pi}=0\right)<5\%$, we have convergence problems due to the following issue. In those states in which the benefits of misreport inflation are low, the government will want to set $\tilde{\pi}=0$. However, as described in our 2-period model, under the assumption that $\tilde{\pi}$ is noisy, this cannot be an equilibrium. This is because if $\tilde{\Pi}_I^{\star}=0$, then the government will set $\tilde{\pi}=\underline{\pi}$ as this has no effect on the posterior and therefore prices.

χ_I so that in our simulations the increase in Argentina's spread due to the detected misreport is around 10% one month after the observed misreport, as measured in the data.

4.2. *Quantitative Results*

In this section we summarize the results of the quantitative model. We start by depicting some untargeted moments as a source of external validation for the model. We then present the optimal policy functions for default and inflation tampering to better understand each government's incentives. Finally, we simulate our calibrated version of the model to provide a measure of the long-run costs of losing reputation. As an additional source of external validation, we show that the model is capable of replicating the dynamics for Argentine spreads for the 2006-2009 period.

4.2.1. *Untargeted Moments*

The second column of Table 6 reports moments based on simulations for the economy. Moments are computed for sample paths without defaults. Consumption is around 10% more volatile than output and the trade balance is highly counter-cyclical, consistent with empirical evidence for Argentina.

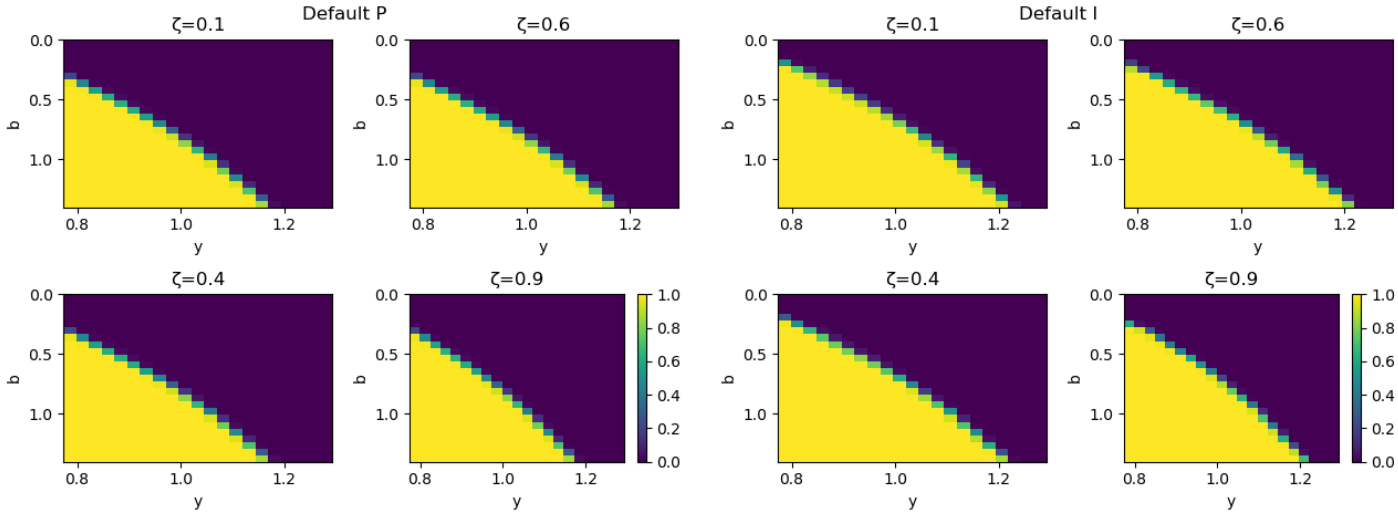
Table 6. Untargeted Moments

Moment	Data	Model
$std(c)/std(y)$	1.09	1.12
$corr(TB/y, y)$	-0.88	-0.74

4.2.2. *Optimal Policies*

Figure 11 depicts the default sets for both the patient (left-panel) and impatient (right-panel) government for different combinations of (y, b, ζ). The light-colored area is the state-space where the government defaults while the dark-colored the one in which it repays. For either type of government, default incentives are higher with lower ζ. Furthermore, the default set of the impatient type is (weakly) larger than that of the patient.

FIGURE 11. Default Sets

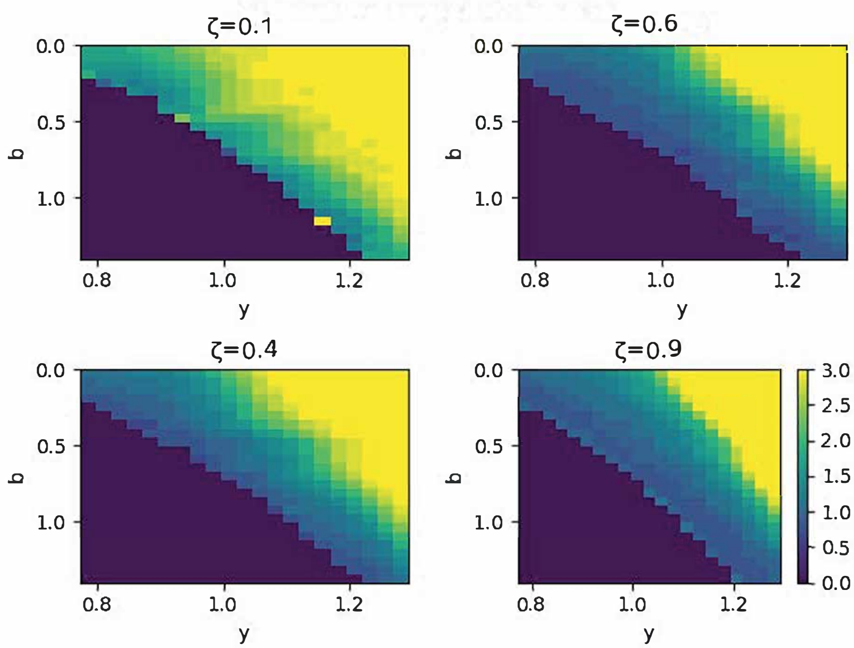


(A) Inflation-linked debt and default cost

(B) Inflation-linked and nominal debt

Notes: Optimal default sets. Yellow area denotes the combinations of output (y) and stock of debt (b) in which the government optimally chooses to default.

FIGURE 12. Optimal Underreport of Inflation



Notes: Optimal inflation misreport. Yellow are denotes the combination of output (y) and stock of debt (b) in which te government optimally chooses to misreport the inflation rate up to the allowed limit.

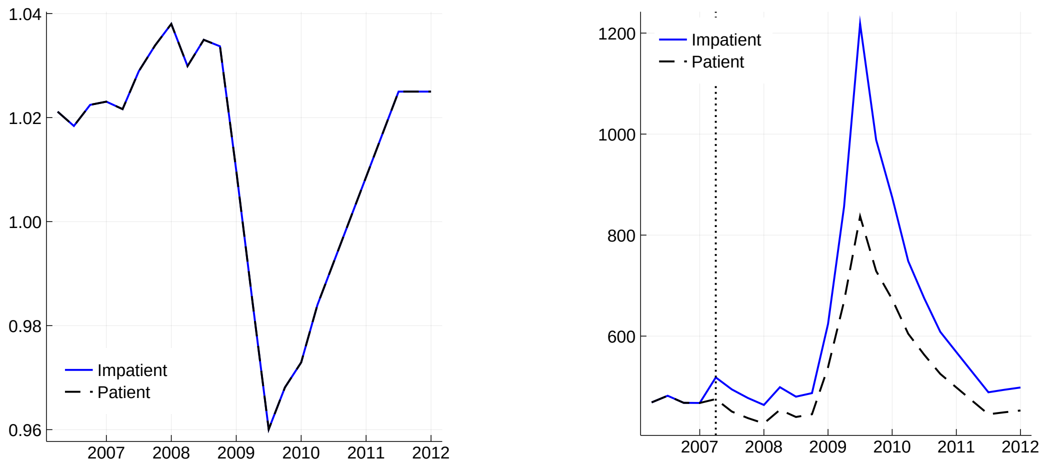
Next, we analyze the policy on inflation tampering shown in figure 12. Given a value of ζ, we observe that misreport is larger in "good times", in particular, as we move farther away from the default region. This is because in "good times" prices are almost unaffected by changes in ζ', and the costs of lying about inflation are very low. In contrast, prices are very sensitive to changes in reputation during "bad times". In addition, when comparing across different ζ we observe that a higher reputation ζ is associated with lower incentives to misreport. That is, for a given (y, b) an initially higher (lower) reputation creates incentives to keep that high (low) reputation, suggesting the existence of a high persistence in the reputation variable in the model. This feature is relevant to replicate the observed dynamics for Argentina's spreads post 2007.

4.2.3. *Simulations*

In this section we simulate the Argentine economy during the 2006-2009 period. We feed in the observed evolution of GDP's HP cycle during this period and analyze two different scenarios. In the first scenario (blue solid line), we assume the government is of the P-type up until 2007:q1 and switch to the I-type after that. To be in line with data counterpart, we also assume that the message $m = L$ is realized in the first two quarters of 2007, all the rest of the periods being $m = NL$. On the second scenario (black dashed line), we assume the government is of the P-type. In this case, the realized message is assumed to be $m = NL$. Both scenarios start with the same level of debt and prior. To isolate the effect of changes in reputation, we impose the optimal path of debt observed on the second scenario to the first one.

Figure 13 shows the result of the simulation exercise. On the left panel we have the assumed evolution of output, which is the same under both scenarios. On the right panel we have the simulated spreads. In Scenario 1, spreads start to decouple in 2007 as the message $m = L$ is realized and react by significantly more when the crisis hits relative to Scenario 2. Furthermore, spreads remain relatively well after recovery (even when $m = NL$).

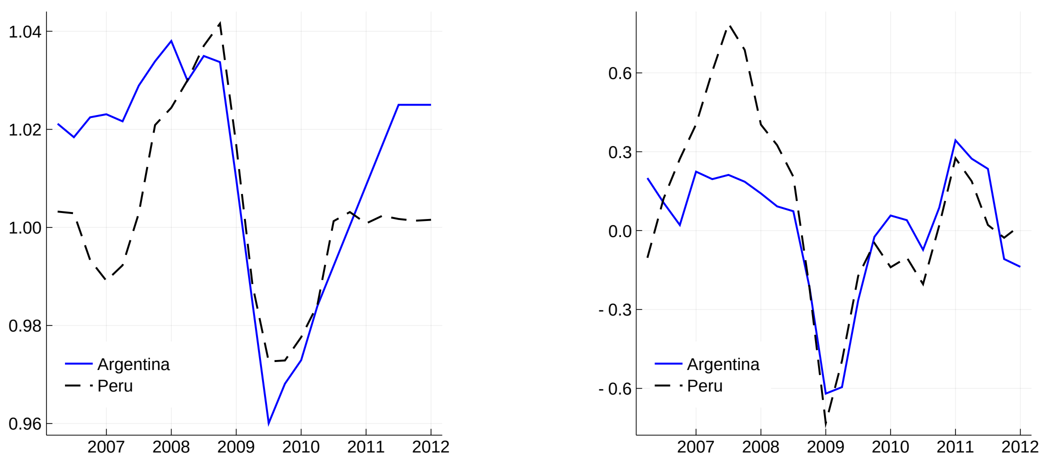
Figure 13. Simulations: Argentina in 2007-2009



Output

Spreads (in bps)

Figure 14. Data Counterfactual: Argentina and Peru

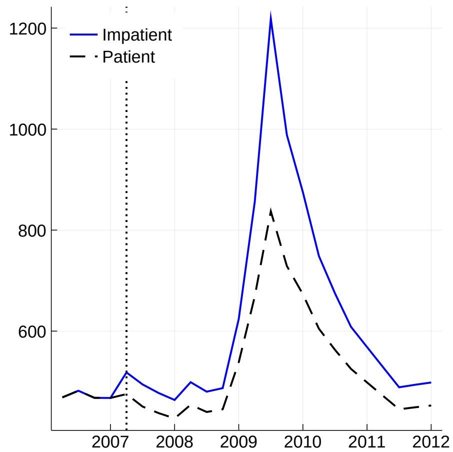


Output

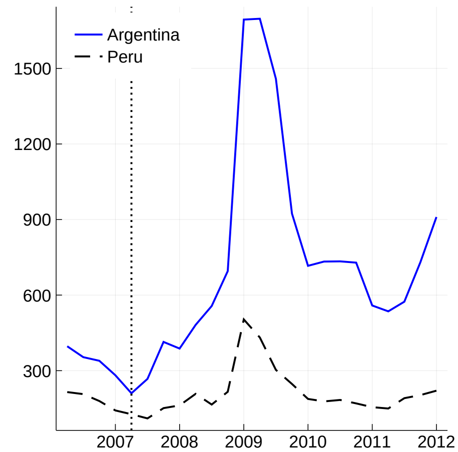
Stocks

The difference in the simualted evolution of spreads is not estranged to reality. As figure 14 shows, not only the evolution of debt but also that of output and stocks were similar for Argentina and Peru. This suggests that fundamentals and the market participant's expectations of growth were similar across the two countries. However, as the right panel of figure 15 shows, the dynamics for spreads were quite different. Just as in the model, Argentine spreads started to decouple in 2007:q1 and remained higher even after macroeconomic fundamentals recovered post Great Recssion.

FIGURE 15. Comparison Model and Data



Simulated spreads (in bps)



Data spreads (in bps)

5. Conclusion

In this paper, we study the effects of non-standard default policies on government's borrowing costs. We define non-standard policies as those that lead to a partial reduction in the stock of government debt but are not perfectly observable by lenders. An example of such policies is a misreport of inflation in the case of inflation-indexed bonds. We first formulate a two-period model to show the trade-offs at hand. We show that incentives to misreport inflation are state-contingent and that government actions are heavily influenced by market beliefs. Our empirical analysis shows that macroeconomic fundamentals are not always enough to explain the evolution of sovereign spreads. In particular, using Argentina as a case of study, we show that a misreport of inflation can have a great impact over sovereign spreads in the short-run, because it affects government's reputation. We use the empirical results to calibrate our quantitative model and use this model to asses the long-term consequences of a deterioration in government's reputations. The model suggests that the dynamics of reputation can be quite persistent, which allows to explain the observed decoupling of Argentina's spreads with respect to the rest of the region.

More generally, our findings highlight the role of reputation in international debt markets. This analysis is especially relevant for policymakers and market participants when considering the benefits and costs of trading more complex state-dependent debt contracts. Our analysis is partial in the sense that we do not study the effects of moral hazard at issuance, but it is insightful on the effects it can have once debt contracts are in place. In this sense, the paper's findings suggest that to ensure market liquidity for this type of contracts, their design should be robust to moral hazard concerns. For example, by having a non-biased third party entity reporting the true value of inflation. We leave a more detail analysis of optimal contracting to future research.

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Appendix A. Algorithm to Solve the 2-period Model

In this appendix, we outline the algorithm to solve for the equilibrium in the Two-period model.

(1) Guess $\tilde{\Pi}_I^\star$. Of course, $\tilde{\Pi}_P^\star = 0$.
(2) Using that guess compute $\zeta'\left(m, \tilde{\Pi}_I^\star\right)$ for $m = \{L, NL\}$, using equation (6).
(3) Use the posterior to compute the price schedule $q\left(m, b, \tilde{\Pi}_I^\star\right)$, for each value of b.
(4) Solve the patient's problem optimal bond policy and compute $b^\star_{P,m}$.
(5) Solve the inpatient's problem:
   (a) Construct a grid for $\tilde{\pi}$ in $[\underline{\pi}, 0]$ and for each point in the grid, solve for optimal $b^*_{I,m}$. Compute: $W_I\left(m, \tilde{\pi}, \tilde{\Pi}_I^\star\right)$
   (b) For each $\tilde{\pi}$ on the grid, compute:

$$P(m = L|\tilde{\pi}) \times W\left(L, \tilde{\pi}, \tilde{\Pi}_I^\star\right) + P(m = NL|\tilde{\pi}) W\left(NL, \tilde{\pi}, \tilde{\Pi}_I^\star\right)$$

   (c) Then just pick the $\tilde{\pi}$ that maximizes the previous expression. Call it $\tilde{\pi}_I^\star$.
(6) Check if $\tilde{\pi}_I^\star$ equals $\tilde{\Pi}_I^\star$. If not, update guess accordingly.

Appendix B. Two-period Model with Endogenous (Informative) Bond Policies

In this appendix, we lift the assumption that bond policies are exogenous and therefore uninformative about the government's type. In particular, we assume that both the P- and I-type can optimally choose b. As bond's are now informative about the government's type, the price schedule will depend not only on b, but also on what lenders expect each type of sovereign to issue.

The timing of events is the same as the one described in Section 2. Let ζ be the initial prior. First, the impatient government chooses $\tilde{\pi}$. Based on $\tilde{\pi}$ message $m = \{L, NL\}$ is realized. After observing m (but not $\tilde{\pi}$) lenders update their posterior (call it ζ'). After the update of beliefs, patient and impatient government choose b. Notice that the choice of b depends on the type of government and also on the realization of the message m. Let $(b^\star_{Im}, b^\star_{Pm})_{m=\{L,NL\}}$ denote the market conjecture about the optimal bond policy for each type of government, for each message m.

After the government chose $\tilde{\pi}$ and after the message m was realized (stage 2, period 1), the impatient government solves the following bond issuance problem, given the market conjecture about the government's policies $\left(\tilde{\Pi}_I^\star, b_{Im}^\star, b_{Pm}^\star\right)$ and the (future) optimal default decision:

$$W_I\left(m,\tilde{\pi};\tilde{\Pi}_I^*,b_{Im}^\star,b_{Pm}^\star\right)=\max_b u\left(c_1\right)+\beta\left\{\int_{b+B(1+\tilde{\pi})}^{\bar{\phi}}u\left(c_2\right)dG\left(\phi_I\right)+\int_{\underline{\phi}}^{b+B(1+\tilde{\pi})}u\left(y_2-\phi_I\right)dG\left(\phi_I\right)\right\} \tag{29}$$

$$\begin{aligned} s.t.\quad & c_1=y_1+q\left(.\right)b\\ & c_2=y_2-b-B\left(1+\tilde{\pi}\right)\end{aligned}$$

For the patient government, the bond issuance problem is simply given by:

$$W_P\left(m,\tilde{\pi}=0;\tilde{\Pi}_I^*,b_{Im}^\star,b_{Pm}^\star\right)=\max_b u\left(c_1\right)+\beta u\left(c_2\right) \tag{30}$$

$$\begin{aligned} st\quad & c_1=y_1+q\left(.\right)b\\ & c_2=y_2-b-B\end{aligned}$$

The optimal misreport of inflation problem is analogous to the one described in the main text. That is,

$$\begin{aligned}\tilde{\pi_I}^*\left(\tilde{\Pi}_I^*,b_{Im}^\star,b_{Pm}^\star\right)=\arg\max_{\tilde{\pi}}&\left\{P(m=L|\tilde{\pi})\times W_I\left(m=L,\tilde{\pi},\tilde{\Pi}_I^*,b_{Im}^\star,b_{Pm}^\star\right)\right.\\ &\left.+P(m=NL|\tilde{\pi})\times W_I\left(m=NL,\tilde{\pi},\tilde{\Pi}_I^*,b_{Im}^\star,b_{Pm}^\star\right)\right\}\\ s.t.\quad \tilde{\pi}\in\left[\underline{\pi},0\right],\underline{\pi}<0\end{aligned} \tag{31}$$

The system of beliefs, after message m is received is the same as in the main text. Lenders have an expectation $\tilde{\Pi}_I^*$ on what the misreport will be. Based on the observed message $m=\{L,NL\}$ and on the expectation $\tilde{\Pi}_I^*$, lenders then update their posterior ζ', using a Bayes-induced function: $\zeta'\equiv\zeta'(m,\tilde{\Pi}_I^*)$. Regardless of the underreport, both messages have positive probability, so Bayes' rule always applies and there are no off-path information sets. Denote by $l\left(m;\tilde{\Pi}_I^*\right)$ the updated log likelihood ratio after message m. Then:

$$\begin{aligned} l\left(m;\tilde{\Pi}_I^*\right)=&l_0+\ln\frac{P\left(m|\tilde{\Pi}_P^*=0\right)}{P\left(m|\tilde{\Pi}_I^*\right)}\\ \zeta'\left(m;\tilde{\Pi}_I^*\right)=&\frac{exp\left\{l\left(m,\tilde{\Pi}_I^*\right)\right\}}{1+exp\left\{l\left(m,\tilde{\Pi}_I^*\right)\right\}}\end{aligned} \tag{32}$$

To ease notation, let $\zeta'\equiv\zeta'\left(m;\tilde{\Pi}_I^*\right)$. The pricing kernel is now given by:

$$q\left(m, b; \tilde{\Pi}_I^*, b^\star_{Im}, b^\star_{Pm}\right) = \begin{cases} \frac{1}{1+r}\left[\zeta' + (1-\zeta')\left[1 - G\left(b + B\left(1+\tilde{\Pi}_I^*\right)\right)\right]\right] & \text{if } b = b^\star_{Pm} = b^\star_{Im} \\ \frac{1}{1+r} & \text{if } b = b^\star_{Pm} \neq b^\star_{Im} \\ \frac{1}{1+r}\left[1 - G\left(b + B\left(1+\tilde{\Pi}_I^*\right)\right)\right] & \text{otherwise} \end{cases} \quad (33)$$

Notice that the last case encompasses those cases in which $b = b^\star_{Im} \neq b^\star_{Pm}$, as well as those out-off-equilibrium paths (i.e., $b \neq b^\star_{Im}$ and $b \neq b^\star_{Pm}$), as we assume that in such cases, lenders assume that the government is of the impatient type.

Algorithm to Solve the Model

Given the discontinuity of the pricing kernel, we cannot compute first order conditions as we did in the main text. The algorithm to solve the model is as follows:

(1) Guess the market conjecture $\left(\tilde{\Pi}_I^\star, b^\star_{I,m}, b^\star_{P,m}\right)$.
(2) Using the $\tilde{\Pi}_I^\star$ guessed, compute $\zeta'\left(m, \tilde{\Pi}_I^\star\right)$ for $m = \{L, NL\}$, using equation (6).
(3) Compute the price schedule $q\left(m, b; \tilde{\Pi}_I^\star, b^\star_I, b^\star_P\right)$, for each value of b and message m, given the set of beliefs (and updated posterior).
(4) Solve the patient's problem: Construct a grid for b and for each point in the grid solve for the optimal $b_{P,m}$, for each message m.
    (a) Given that there is a discrete jump in $q(.)$ when we move from $b = b^\star_{P,m}$ to $b = b^\star_{P,m} + \epsilon$, a global solver has to be implemented.
(5) Solve the inpatient's problem:
    (a) Construct a grid for π.
        (i) For each point in the grid for π and for each message m, compute the optimal bond policy (as in step 4): $b_{I,m}\left(m, \tilde{\pi}; \tilde{\Pi}_I^\star, b^\star_{I,m}, b^\star_{P,m}\right)$ and welfare: $W_I\left(m, \tilde{\pi}; \tilde{\Pi}_I^\star, b^\star_{I,m}, b^\star_{P,m}\right)$
    (b) Compute expected welfare as:

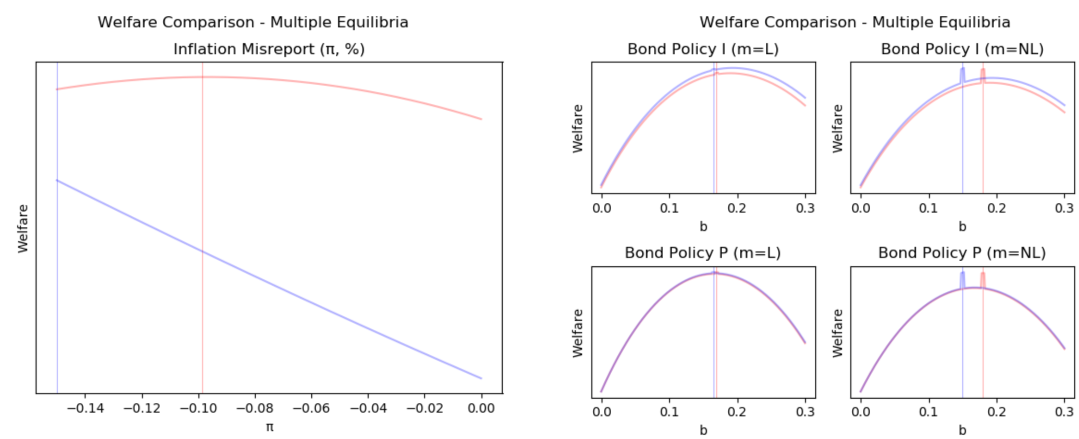
$$P(m = L|\tilde{\pi}) \times W_I\left(L, \tilde{\pi}; \tilde{\Pi}_I^\star, b^\star_{I,m}, b^\star_{P,m}\right) + P(m = NL|\tilde{\pi}) \times W_I\left(NL, \tilde{\pi}; \tilde{\Pi}_I^\star, b^\star_{I,m}, b^\star_{P,m}\right)$$

    (c) Choose $\tilde{\pi}$ that maximizes the previous expression.
(6) Check if $\tilde{\pi}_I$ equals $\tilde{\Pi}_I^\star$ and $b_{j,m} = b^\star_{j,m}$ for any m and $j = P, I$. If not, update guess accordingly.

<u>Multiplicity of Equilibria</u>

Below, we show some examples that indicates the presence of multiple equilibria. In particular, depending on the initial conjecture $\left(\tilde{\Pi}_I^\star, b_{I,m}^\star, b_{P,m}^\star\right)$ (step 1 in the algorithm), we are able to find equilibria with different choices regarding the inflation misreport and the bond policies. Interestingly, there exists equilibria in which the I-type government mimics the bond policy of the patient type (for any message), so that lenders cannot differentiate between the two types by looking at the bonds (as in our baseline model).

Figure 16. Endogenous Bond Policy - Multiplicity of Equilibria



(A) Inflation-linked debt and default cost

(B) Inflation-linked and nominal debt

Notes: We set $B = 0.14$. All other parameters are the same as in the main text.

Figure 16 shows two different equilibria (there are more). The blue line, shows the case in which the impatient government maximizes the misreport ($\tilde{\pi} = \underline{\pi}$), while the red line depicts an equilibrium in which $\tilde{\pi} > \underline{\pi}$. In both cases, there is a pooling equilibrium regarding bond policies (i.e., $b_{I,m} = b_{P,m}$ for any m).

Appendix C. Extended Regression and Market Alpha

Table 7. Panel Regression 2003-2007 (Including Argentina)

	Dependent Variable SP_t^i			
	(ii)	(iii)	(v)	(vi)
$\left(\frac{D}{Y}\right)_{t-1}^c$	0.0307***	0.0293***	0.0137***	0.0035
	(0.0008)	(0.0009)	(0.0025)	(0.0029)
Y_{t-1}^c	-0.0078***	-0.0548***	-0.0120***	-0.0386***
	(0.0021)	(0.0024)	(0.0034)	(0.0034)
$Y_t^{c,US}$	-0.4141***	-0.4481***	-0.2915***	-0.3765***
	(0.0233)	(0.0138)	(0.0096)	(0.0071)
VIX	0.0391***		0.0502***	
	(0.0027)		(0.0013)	
SP	-0.0030***		-0.0014***	
	(0.0002)		(0.0001)	
EEM index	0.0142***		0.0276***	
	(0.0038)		(0.0019)	
ER		-0.0069		-0.0076
		(0.0112)		(0.0052)
SMB		-0.0048		-0.0113
		(0.0180)		(0.0072)
HML		0.0062		-0.0221*
		(0.0286)		(0.0113)
ARG Dummy	1.7844***	1.5733***		
	(0.0466)	(0.0480)		
ARG Dummy * Y_{2006}^c	0.0584***	0.0843***	0.0546***	0.0727***
	(0.0093)	(0.0094)	(0.0099)	(0.0098)
ARG Dummy * Y_{2007}^c	0.3561***	0.4677***	0.3424***	0.4730***
	(0.0177)	(0.0158)	(0.0158)	(0.0154)
Country-dummies	No	No	Yes	Yes
Country-trend dummies	No	No	Yes	Yes

To complement the previous analysis, Table 7 shows the results when Argentina is included in the panel. We include two additional interaction variables (ARG Dummy * Y^c_{2006} and ARG Dummy * Y^c_{2007}) to test whether Argentina's spreads react to the GDP cycle as in the average EM country.[27,28] We find that Argentina spreads were positively correlated with the GDP cycle, particularly in 2007. Overall, the results indicate that the evolution of Argentina's spreads were not aligned with the evolution of the fundamentals. In other words, the market was pricing something else.

As an additional exercise, we consider the EMs sovereigns as an international investors market and compute Argentine's bonds spread alpha against the market. In particular, we run the following regression for 2003-2007:

$$SP_t^{AR} = \alpha_{AR} + \boldsymbol{\beta} \boldsymbol{X}_t + \epsilon_{ARt}$$

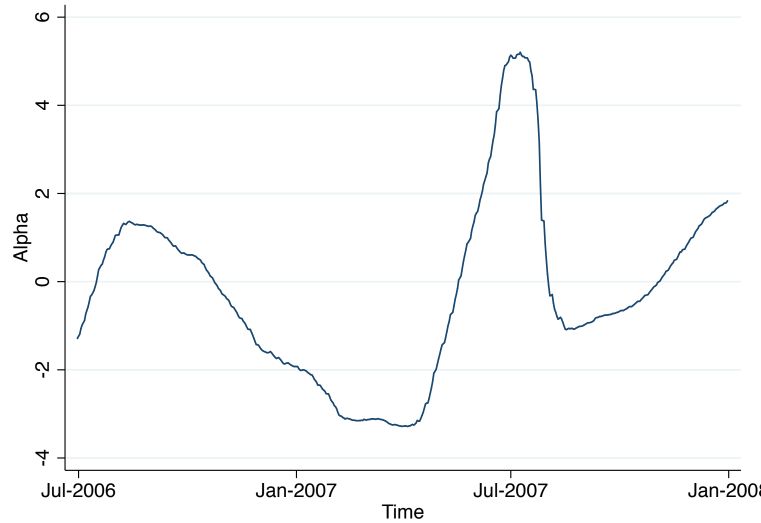
where $\boldsymbol{X}_t$ is a vector of pricing factors, which includes the cross-sectional mean of spreads excluding Argentina ($\bar{SP}_t$) and Fama-French's three factors. If markets are efficient and the pricing factors considered span the entire space of cross-sectional returns, then the alpha of the regression has to be zero. Since we are considering spreads on yields, a positive alpha implies that investors require an excess return to hold Argentinean sovereign debt. We expect this measure to be positive during the first semester of 2007, as investors penalize that particular asset for the government's inflation tampering.

Figure 17 confirms our prior. It shows the alpha coefficients of a 100-day rolling window daily regression of Argentine spreads onto $\boldsymbol{X}_t$. The figure suggests a significant increase in the market alpha during the first semester of 2007, which we interpret as market participants pricing a reduction on the government's reputation.

[27]We do not include interactions for the 2003-2005 years, given that Argentina was in default during that period. We treat those observations as missing values.

[28]Argentina's stock of debt did not change significantly during the 2006-2007 period. Hence, we do not include interactions for the $\left(\frac{D}{Y}\right)^c$ variables.

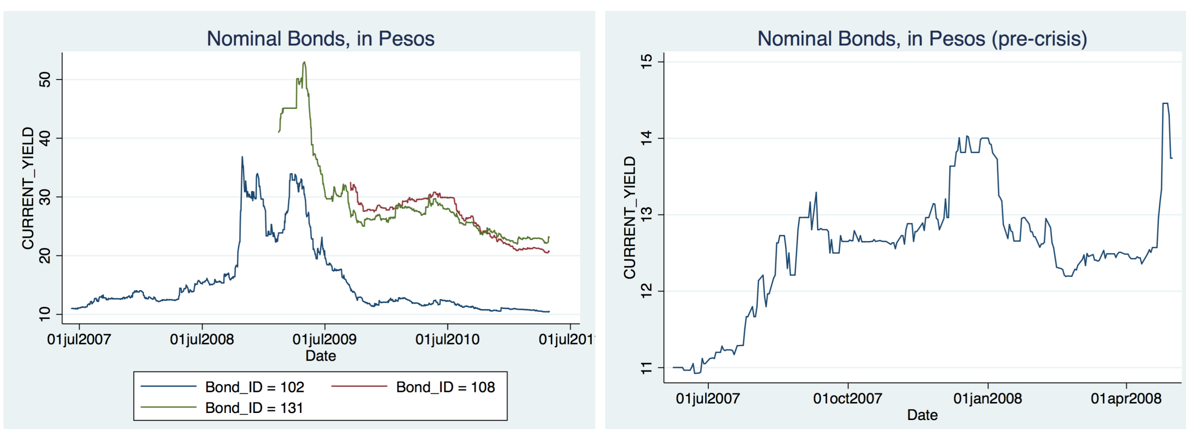
Figure 17. Market Alpha for Argentina



Notes:

Appendix D. Analysis of the Break-Even Inflation Rate

Figure 18. Nominal (Pesos) Bonds



(A) Inflation-linked debt and default cost (B) Inflation-linked and nominal debt

Notes:

– Almost no bonds in pesos were trading during 2007 (at least from what we got in Bloomberg).

– Following graph describes the only bonds in pesos available.

– Hence, we use bonds in dollar and the forward price of the dollar to back up the break-even inflation rate.

Changes in Break-Even Inflation as a proxy for $\tilde{\pi}_t^u$

Using the yields of IIBs and nominal bonds, we compute the break-even inflation (BE). Let $Yield_m^{\$}$ be the yield of a nominal bond (in pesos) with maturity m. Let $Yield_m^{IIB}$ be the yield of an inflation indexed bond with maturity m. $Yields$ are simply computed as the coupon divided by the market price of the bond:

$$Yield_m = \left(\frac{\text{Coupon}}{\text{Market Price}}\right)_m$$

Then the break-even inflation is given by:

$$BE_m = Yield_m^{\$} - Yield_m^{IIB}$$

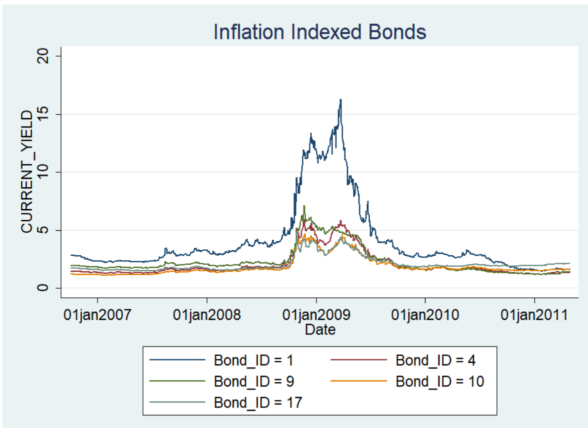
The previous specification indicates that if the market expects a higher (announced) inflation rate in the future, then the BE should increase (as the price of inflation-indexed bonds should increase). However, in the event that the government underreports inflation we should observe a fall in the BE if the market did not anticipate such misreport (as the price of inflation-linked bonds decrease).

A major set-back is that there are only three bonds in pesos actively trading during the considered period. Moreover, there is only one bond for which we have yields data during 2007 and the first observation is only for July (six months after the government started misreporting inflation).[29] To circumvent the issue of limited data, we proceed as follows. We will construct BE using the yields of nominal bonds in dollars (call it $Yield_m^{US\$}$) and the forward price of the dollar. Let F_j be the forward price of the dollar, j months from today. Let$\delta_j^e \equiv \frac{F_j - F_0}{F_0}$ be the expected devaluation rate in j-periods. We choose bonds with semi-annual coupons, and use the 6 months forward rate to compute the expected depreciation six months from now. Therefore, the yields are given by:

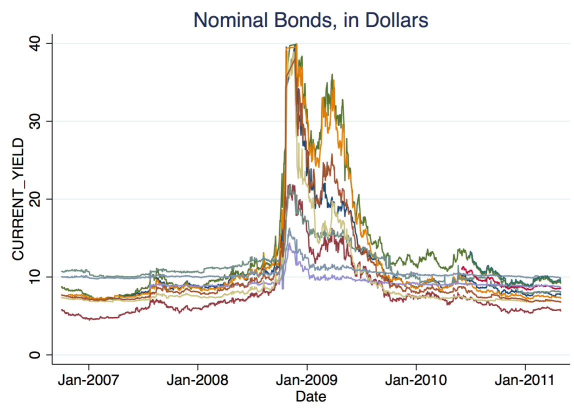
[29]At least in the Bloomberg terminal. This is probably because Argentina exited a default in 2005, and the renegotiated bonds were set in dollars. [ADD?]

$$
\begin{aligned}
Yield_m^{\$,US\$} &= \frac{\text{Coupon} \times (1+\delta_6^e)}{\text{Price}} \\
&= Yield_m^{US\$}\,[1+\delta_6^e] \\
BE_m &= Yield_m^{\$,US\$} - Yield_m^{IIB}
\end{aligned}
$$

FIGURE 19. Current Yields



(A) Inflation-linked debt and default cost



(B) Inflation-linked and nominal debt

Notes:

Figure 19 plots the yields of inflation-indexed bonds (left panel) and for nominal bonds in dollars (right-panel).

To compute the BE inflation, we need to consider bonds with the same maturity. To do that, we group bonds in 3-years maturity bins and compute average yields for each bin. In total there are five 3-year bins starting from 2010 (i.e. 2010-2012, ..., 2022-2024). Bonds with maturities larger than 2025 are group altogether as a sixth bin.

Appendix E. Description of Argentina's Inflation Announcements

Lists of all the days in which the Argentine government reported the inflation rate, between 2007 and 2010. The sources from which these dates where retrieved are summarized below (links are in Spanish).

Table 8. Reporting Dates

Event	Inflation for:	Reported Day	Monthly Rate (%)	Event	Inflation for:	Reported Day	Monthly Rate (%)
1	Jan-07	2/5/2007	1.14	25	Jan-09	2/11/2009	0.53
2	Feb-07	3/5/2007	0.30	26	Feb-09	3/11/2009	0.43
3	Mar-07	4/11/2007	0.77	27	Mar-09	4/14/2009	0.64
4	Apr-07	5/4/2007	0.74	28	Apr-09	5/13/2009	0.33
5	May-07	6/5/2007	0.42	29	May-09	6/11/2009	0.33
6	Jun-07	7/5/2007	0.44	30	Jun-09	7/14/2009	0.42
7	Jul-07	8/7/2007	0.50	31	Jul-09	8/12/2009	0.62
8	Aug-07	9/7/2007	0.59	32	Aug-09	9/4/2009	0.83
9	Sep-07	10/5/2007	0.80	33	Sep-09	10/14/2009	0.74
10	Oct-07	11/6/2007	0.68	34	Oct-09	11/12/2009	0.80
11	Nov-07	12/6/2007	0.85	35	Nov-09	12/11/2009	0.83
12	Dec-07	1/7/2008	0.93	36	Dec-09	1/15/2010	0.93
13	Jan-08	2/7/2008	0.93	37	Jan-10	2/12/2010	1.04
14	Feb-08	3/6/2008	0.47	38	Feb-10	3/12/2010	1.25
15	Mar-08	4/10/2008	1.13	39	Mar-10	4/14/2010	1.14
16	Apr-08	5/9/2008	0.83	40	Apr-10	5/12/2010	0.83
17	May-08	6/10/2008	0.56	41	May-10	6/14/2010	0.75
18	Jun-08	7/11/2008	0.64	42	Jun-10	7/14/2010	0.73
19	Jul-08	8/11/2008	0.37	43	Jul-10	8/13/2010	0.80
20	Aug-08	9/11/2008	0.47	44	Aug-10	9/15/2010	0.74
21	Sep-08	10/10/2008	0.51	45	Sep-10	10/15/2010	0.72
22	Oct-08	11/11/2008	0.43	46	Oct-10	11/12/2010	0.84
23	Nov-08	12/10/2008	0.34	47	Nov-10	12/16/2010	0.73
24	Dec-08	1/13/2009	0.34	48	Dec-10	1/14/2011	0.84

Appendix F. Bootstrap Procedure for Standard Errors

In this appendix, we describe the procedure followed to compute standard errors and confidence intervals in Section 3.2.1. We follow Hebert and Schreger (2017) and use a stratified bootstrap procedure. The benefit of this procedure is that offers "asymptotic refinements for the coverage probabilities of tests". Given that our IV estimator is based on a small number of observations, these refinements provide significant improvements over first order asymptotics. The procedure is as follows.

- We use 1,000 repetitions of a stratified bootstrap, re-sampling with replacement from our set of events and non-events, separately.
- For each sample, we verify that our identification assumption (i.e., $\sigma^2_{\eta,E}/\sigma^2_{\eta,N} > 1$) holds. We discard those samples in which the assumption does not hold.
- For each repetition k, we compute the t-statistic $t_k = \frac{\hat{\alpha_k}-\hat{\alpha}}{\hat{\sigma_k}}$, where $\hat{\alpha}$ is the point estimate in the actual data, $\hat{\alpha}_k$ is the point estimate in the bootstrap replication k, and $\hat{\sigma_k}$ is the heteroskedasticity-robust standard deviation of the estimator from bootstrap sample k.
- To compute the 95% CI, we first compute the 2.5^{th} and 97.5^{th} percentiles of the t-statistic t_k. We denote these percentiles as $t_{2.5}$ and $t_{97.5,}$ respectively.
- The reported 95% CI for $\hat{\alpha}$ is: $[\hat{\alpha} + t_{2.5} \times \hat{\sigma}, \hat{\alpha} + t_{97.5} \times \hat{\sigma}]$.
- We compute the 99% CI in a similar way and use them to assign asterisk in the tables.

Appendix G. The Event Study Methodology

In this section we present a standard event study to estimate the effect of inflation misreport on Argentina's sovereign spreads.[30] The identifying assumption is that changes in Argentina's BE inflation during the event windows are driven exclusively by that announcement or other idiosyncratic shocks (η_t). Let NE denote the set of non-event days and let $L =\mid NE \mid$. We first estimate a factor model on the non-event-days,

$$\Delta R_t = \phi_0 + \phi_1 X_t + \nu_t \tag{34}$$

where X_t is a vector of controls. We then use those estimates to generate a time series of abnormal EMBI changes and to estimate its variance (assuming that errors are homoskedastic).

[30]The methodology used was first described in Campbell et al. (1997).

That is,

$$\Delta R_t^A = \Delta R_t - \hat{\phi}_0 - \hat{\phi}_1 X_t$$
$$\hat{\sigma}_R^2 = \frac{1}{L} \sum_{t \in NE} (\Delta R_t^A)^2$$

The vector X_t includes global factors that may affect changes in Argentina's EMBI spreads. We use the VIX index (implied volatility of the S&P 500), the S&P 500 index as a broad measure of equity returns, the MSCI Emerging Markets ETF (equity) index and the change in Asia's EMBI. We use Asia (instead of an index composed by Latin American countries) to ensure that movements in this index are not driven by changes in the Argentine economy.

Next, we classify our event windows into three categories, depending on the observed change in the BE inflation (ΔBE). Let $\mu_{\Delta BE}^{E,j}$ be the average of ΔBE in the the event window j and let $(\mu_{\Delta BE}^{NE}, \sigma_{\Delta BE}^{NE})$ be the mean and standard deviation of ΔBE for the "non-event" days. From the pool of event days we create three categories:

(1) If $\mu_{\Delta BE}^{E,j} < \mu_{\Delta BE}^{NE} - 0.5\sigma_{\Delta BE}^{NE}$ we label the event window j as a "bad news" event (BNE).
(2) If $\mu_{\Delta BE}^{E,j} > \mu_{\Delta BE}^{NE} + 0.5\sigma_{\Delta BE}^{NE}$ we label the event window j as a "good news event" (GNE).
(3) Otherwise the event window j is labeled as "no news event" (NNE).

For each category $k = \{BNE, GNE, NNE\}$, we compute the cumulative abnormal EMBI changes over all events of the same type k: $CAR_k = \sum_{t \in k} \Delta R_t^A$. Notice that CAR adds abnormal changes in different windows (non consecutive days). Finally, we report the $J1$ statistics described in Campbell et al. (1997):

$$J1_k \equiv \frac{CAR_j}{\sqrt{L_k \times \hat{\sigma_R}^2}} = \frac{C\bar{A}R_j}{L_k^{-\frac{1}{2}} \times \hat{\sigma_R}}$$

where $L_k =\mid E_k \mid$ denotes the total number of days for each type of event k and $C\bar{A}R_k = \frac{CAR_k}{L_k}$. Under the null hypothesis that the events have no effect on ΔR, $J1_k$ is asymptotically distributed as a standard normal variable. The problem is that there are few events in each category and therefore asymptotic normality is a poor approximation. With that caveat in mind, Table 9 reports the results:

TABLE 9. Event Study

3-day Window

Type	**# of Events**	**# Obs**	$\bar{CAR}$	J_1	$\Delta\bar{BE}$
GNE	1	3	−0.0093	−0.76929	0.077078
NNE	13	39	0.005472	1.65803	0.0007
BNE	1	3	0.011446	0.947104	−0.129101

5-day Window

Type	**# of Events**	**# Obs**	$\bar{CAR}$	J_1	$\Delta\bar{BE}$
GNE	0	0	-	–	-
NNE	13	65	0.003981	1.527	0.006512
BNE	2	10	0.019086	2.966	−0.11002

From this table we observe that the announcement of inflation was basically informative in two dates only. In the rest of the announcements, the BE inflation did not change much, and therefore it is categorized as *No News*. In fact, this result suggests that the market rapidly realized that the government was lying about inflation. Finally, notice that the CAR is almost 2% in the bad news event. This implies that Argentina's EMBI increased around 2% daily every time the market realized that the government lied about inflation. After 5 days (according to the second table), the cumulative abnormal EMBI change after the market realized the lie was about 9.6%.