Austerity*

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Abstract

We study the optimal debt and investment decisions of a sovereign with private information. The separating equilibrium is characterized by a cap on the current account. A sovereign repays debt amount due that exceeds default costs in order to signal creditworthiness and smooth consumption. Accepting funding conditional on investment/reforms relaxes borrowing constraints, even when investment does not create collateral, but it depresses current consumption. The model contains the signalling elements emphasized by creditors in the Greek austerity programs and is consistent with the reduction in the loans issued by Greece and their interest rate following the 2015 election.

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1 Introduction

Asymmetric information is a pervasive feature of sovereign debt markets: A sovereign may know more about the weights she places on the different constituencies affected by her repayment choice; about the true state of the country's repayment capacity; and so on.[1] Such information frictions tend to be exaggerated around times of government change as creditors struggle to determine the sovereign's creditworthiness. For instance, default risk premia in Brazil shot up around the time of the election of President Lula in 2002 but came down sharply after his government adopted strict fiscal consolidation measures. A similar picture emerged in Greece following the 2015 electoral win of Syriza, a party that had campaigned on the basis of a threat to default on the country's external debt but ended up doing a U-turn.

In this paper, we develop a model of sovereign debt that helps shed light on how incomplete information shapes the strategies of the borrower and her creditors and determines debt quantities and prices. The model is in the spirit of Cole *et al.* (1995) but features private information about the default cost rather than the discount factor of the government. More importantly, it also includes investment. The key questions we address are through which means, and to what effect, a sovereign borrower chooses to signal her type to the creditors. Our framework proves informative in the analysis of the Greek sovereign debt crisis.

In our setup, the differences in default costs across types are not publicly observable but may be revealed through the actions of the government. We show that, under the Cho and Kreps (1987) intuitive criterion, there is a unique separating equilibrium in which a government with high default costs—a creditworthy one—communicates its type by repaying debt due and limiting the country's current account deficit. But in spite of the fact that the government's creditworthiness is not in doubt in equilibrium, the threat of mimicking by less creditworthy types implies that separation involves debt rationing. As in Green and Porter (1984) separation thus does not support the full information

[1] A particularly striking example of asymmetric information concerns Greek public debt and budget deficit statistics during the run-up to the recent debt crisis when the Greek government misled creditors about the actual level of indebtedness.

outcome, in contrast to standard results in the literatures on asymmetric information credit rationing (Bester, 1985) or sovereign debt with private information (Cole *et al.*, 1995).[2]

An important and consequential difference of our setup from those in the extant literature concerns the menu of signals available for managing the expectations of creditors. In the literature, debt repayment or debt contracting is the only instrument available.[3] In our model, investment (or, more broadly, structural reforms that enhance future productivity) represents an additional signalling device. We show that being able to choose not only the total amount of national spending but also its composition has the following implications: First, it makes it easier for the borrower to successfully communicate her type. Second, it increases the welfare of creditworthy borrowers in spite of the fact that it requires them to trade scarce, current consumption for future consumption. And third, the investment based signal may even work when little or no debt is outstanding.

It is important to note that in our model, investment alleviates the borrowing constraint *irrespective* of whether it contributes to collateral creation or not:[4] In the complete information sovereign debt model, higher investment enables higher current borrowing by increasing the cost of future default. In our model, it does so (also) by credibly informing creditors about the sovereign's high cost of future default. The role of investment or reforms as a signalling device derives from the fact that higher creditworthiness effectively induces a lower time discount rate although preferences are the same across types: At any level of current consumption, an extra unit of income in the future is worth more to a creditworthy than to a non-creditworthy type because the former will repay debt due while the latter will not. By choosing the level of investment to sufficiently steepen the profile of resources available for consumption and debt service, the creditworthy type can exploit this fact in order to induce separation.

The importance of informational frictions for the Greek credit events is apparent in

[2]See Canzoneri (1985) for an application of the Green and Porter (1984) result to monetary policy.

[3]Following Cole *et al.* (1995), important recent contributions include Sandleris (2008), D'Erasmo (2011), Perez (2017), Phan (2017), and Dovis (2019). Gibert (2016) is closest to our work in terms of motivation, explicitly treating austerity as a signalling device.

[4]The case where investment increases collateral is well understood (Obstfeld and Rogoff, 1996, ch. 6.2).

the repeated statements of German officials who explicitly justified austerity in terms of signalling under conditions of uncertainty about the creditworthiness of the Greek government.[5] Moreover, our model seems consistent with—and can make sense of—key patterns observed in the recent sovereign debt experience in Greece. After the February 2015 elections were won by Syriza, a party that had run a campaign based on the threat to default on the country's external debt, the government did not declare default. Instead, Greece and her creditors signed a new, quite stingy loan arrangement laden with stringent reform requirements (the third Greek Program) but, at the same time, with cheaper financing than under the second Greek program. Following the agreement, investors seemed to substantially upgrade their beliefs about the government's creditworthiness.

Through the lens of our model, Syriza's campaign had raised serious doubts about the government's type but the acceptance of limited fresh funding, at favorable interest rates, subject to an expanded set of reform commitments helped convince lenders that the Syriza government actually was creditworthy.[6] In contrast, the standard sovereign debt model without information frictions (Eaton and Gersovitz, 1981; Obstfeld and Rogoff, 1996) would be challenged to explain these features. In that model, an increase in the perceived creditworthiness of a sovereign induces a lower interest rate and *more* lending.

The term austerity has been extensively used in the policy debate to refer to—public and total—current spending reductions and associated declines in national consumption that are triggered by doubts about the repayment capacity of the government. Sovereign debt models are designed to analyze precisely the relationship between lack of commitment and consumption smoothing, so they are well suited to analyze austerity.[7] They also provide a natural definition of it as the gap between actual consumption and the level of consumption under commitment. Lack of commitment generates an austerity gap and leads to consumption backloading. The addition of private information introduces another

[5]Gibert (2016) reports support for the signalling role of austerity from a panel of 58 OECD and emerging market economies since 1980.

[6]The implementation of reforms was a key element of the new loan contract. This could be because they create collateral, as suggested by the standard model, or, because they effectively signal the government's commitment to meet costly obligations such as debt repayment, as in our model.

[7]Conesa *et al.* (2016) and Balke and Ravn (2016) are representative examples. These papers seek to determine the size and composition of optimal austerity in terms of taxes and transfers.

consumption gap and accentuates the degree of consumption backloading.

The rest of the paper is organized as follows. Section 2 lays out a simple endowment economy and characterizes pooling and separating equilibria. Section 3 introduces investment. Section 4 discusses the sovereign debt crisis in Greece through the lens of the model. Section 5 concludes.

2 Endowment Model

2.1 Environment

We consider a two-period setup, $t = 1, 2$, with a sovereign borrower (the government, the country) and international lenders (the financial market, creditors, investors). The borrower chooses whether to repay outstanding debt and how much new debt to issue. Lenders form beliefs about the government's creditworthiness and offer a price for the new debt.

Default is costly as it triggers temporary income losses (see, e.g., Arellano, 2008): A default at date t reduces the country's exogenous income y_t by the fraction $\lambda \geq 0$ so that income in a period equals y_t when there is no default and $y_t(1 - \lambda)$ when there is default. There is no exclusion from credit markets following default.

The default cost parameter λ takes one of two values, $\lambda^l \geq 0$ or $\lambda^h > \lambda^l$. We refer to a government facing λ^h (λ^l) as a government "with high (low) creditworthiness" or simply a "high (low) type." The values of λ^h and λ^l as well as the prior probability that a government is a high or low type are common knowledge but the actual realization is private information to the sovereign. The prior probability that a given country is of the high type is $\theta \in (0, 1)$.

The government values expected discounted utility from domestic consumption (see below). The investors require an expected gross rate of return $\beta^{-1} > 1$. Short-sales are ruled out. Following the signalling literature (see, e.g., Kreps and Sobel, 1994) we do not model the reasons why investors behave competitively. Possible interpretations of the price function include Bertrand competition between symmetric, equally informed, risk neutral lenders, or a take-it-or-leave-it offer by the government.

Events unfold as follows. At date $t = 1$, the government chooses the repayment rate, $r_1 \in \{0, 1\}$, on maturing debt, b_1, and issues new zero coupon debt, $b_2 \in [0, \infty)$. Lenders observe these actions and form the posterior belief, θ_1. They then set a price, $q_1 \in [0, \beta]$, which reflects the posterior and the required return. Finally, at date $t = 2$, the government chooses the repayment rate, $r_2 \in \{0, 1\}$, on b_2.

Since the government at date $t = 1$ cannot commit its successor (or, future self) the choice of repayment rate in the second period, r_2, is mechanical: It equals zero when the maturing debt exceeds the default costs, and unity otherwise. That is, when the government is of type i,

$$r_2^i(b_2) = \begin{cases} 1 & \text{if } \lambda^i y_2 \geq b_2 \\ 0 & \text{if } \lambda^i y_2 < b_2 \end{cases}, \quad i = h, l. \tag{1}$$

Accordingly, utility from domestic consumption at date $t = 2$ equals

$$u\left(y_2 - \min[y_2\lambda^i, b_2]\right), \quad i = h, l,$$

where the felicity function u is increasing and strictly concave. Conditional on the price q_1, the payoff of a government of type i at date $t = 1$ is thus given by

$$U^i(r_1, b_2; q_1) \equiv u\left(y_1 - y_1\lambda^i(1 - r_1) - b_1 r_1 + q_1 b_2\right) + \delta u\left(y_2 - \min[y_2\lambda^i, b_2]\right), \quad i = h, l,$$

where the discount factor $\delta \in (0, 1)$. Following the sovereign debt literature, we focus on the case of interest where δ is sufficiently small and/or the output profile sufficiently steep such that if the country faced a bond price of β it would borrow.

Note that the timing protocol corresponds to a standard signalling game: The borrower sends a signal, (r_1, b_2), and the lender interprets this signal and responds by offering a signal dependent price.

2.2 Equilibrium

We restrict attention to pure strategies. A perfect Bayesian *equilibrium* is a type dependent signal (repayment rate and debt issuance),

$$r_1^\star : \{\lambda^l, \lambda^h\} \to \{0, 1\},$$
$$b_2^\star : \{\lambda^l, \lambda^h\} \to \mathbb{R}_+;$$

a signal dependent posterior belief,

$$\theta_1^\star : \{0,1\} \times \mathbb{R}_+ \to [0,1];$$

and a price that reflects the signal and the beliefs,

$$q_1^\star : \{0,1\} \times \mathbb{R}_+ \to [0,\beta],$$

such that the following conditions are satisfied: The signal is optimal,

$$(r_1^\star, b_2^\star)(\lambda^i) = \arg \max_{(r_1,b_2)\in\{0,1\}\times\mathbb{R}_+} U^i(r_1, b_2; q_1^\star),\ \ i = h, l;$$

the posterior satisfies Bayes' law where applicable,

$$\theta_1^\star(r_1, b_2) = \text{prob}(h|r_1, b_2; r_1^\star, b_2^\star) \ \ \text{when} \ \ \text{prob}(r_1, b_2; r_1^\star, b_2^\star) > 0;$$

and lenders break even,

$$q_1^\star(r_1, b_2) = \beta\{\theta_1^\star(r_1, b_2) r_2^h(b_2) + (1 - \theta_1^\star(r_1, b_2)) r_2^l(b_2)\}.$$

The first equilibrium requirement that the signal is optimal implies (self-)selection constraints,

$$U^i(r_1^\star(\lambda^i), b_2^\star(\lambda^i); q_1^\star) \geq U^i(r_1, b_2; q_1^\star),\ \ (r_1, b_2) \in \{0,1\} \times \mathbb{R}_+,\ \ i = h, l. \tag{2}$$

For now, we characterize these constraints under the assumption that the immediate cost of defaulting is lower than the cost of repaying the initial debt for a low type, but higher for a high type:[8]

$$\lambda^l < b_1/y_1 < \lambda^h = \infty. \tag{L}$$

A high type thus always repays and any choice other than $r_1 = 1$ reveals a low type. Consequently, the Cho and Kreps (1987) intuitive criterion restricts off-equilibrium beliefs to $\theta_1^\star(0, b_2) = 0$ for all b_2.

The repayment rate in the second period—given by condition (1)—together with the requirement that the lenders break even imply the price function

$$q_1^\star(r_1, b_2) = \begin{cases} \beta & \text{if } b_2 \leq \lambda^l y_2 \\ \beta\theta_1^\star(r_1, b_2) & \text{if } \lambda^l y_2 < b_2 \leq \lambda^h y_2 \\ 0 & \text{otherwise} \end{cases}. \tag{3}$$

[8]See subsection 2.3 for the case where both λ^l and λ^h fall short of b_1/y_1.

In conclusion, an equilibrium subject to condition (L) satisfies (2), (3), Bayes' law where applicable, and $\theta_1^\star(0, b_2) = 0$.

We distinguish between *pooling* and *separating equilibria*. In a pooling equilibrium, both types send the same signals and lenders do not change their prior beliefs because the signal is not informative. In a separating equilibrium, the two types send different signals and along the equilibrium path the posterior beliefs of lenders equal either zero or unity because the signal is informative. To eliminate the usual multiplicity of equilibria we refine off-equilibrium beliefs using the intuitive criterion.

We now characterize the separating and pooling equilibria. To simplify the exposition we assume that $\lambda^l = 0$.

2.2.1 Separating Equilibria

Any equilibrium features two signals from the high type, namely, a repayment decision, $r_1^\star(\lambda^h) = 1$ and a quantity of debt issued, $b_2^\star(\lambda^h) = b_2^h$; and two signals by the low type, namely, a repayment decision, $r_1^\star(\lambda^l)$, and a quantity of debt issued, $b_2^\star(\lambda^l) = b_2^l$. In a separating equilibrium, at least one of the two signals must differ across the two types, and the posterior formed by lenders thus equals zero or one along the equilibrium path. In particular, $\theta_1^\star(1, b_2^h) = 1$.

Note that $r_1^\star(\lambda^l)$ must equal zero in a separating equilibrium. To see this, suppose instead that a low type repays in equilibrium and offers to issue b_2^l. Since a separating equilibrium requires that at least one of the two signals differs across the two types, b_2^l must differ from b_2^h in this case. This debt choice identifies the borrower as the low type and leads creditors to form the posterior $\theta_1^\star(1, b_2^l) = 0$ and to offer the price $q_1^\star(1, b_2^l) = 0$, so the borrower receives zero funds. But this implies that it cannot be optimal for the low type to repay since repayment is costly and does not yield any benefit. In equilibrium, the low type therefore defaults. As the equilibrium outcome is the same for any $b_2^l \neq b_2^h$, we restrict attention without loss of generality to the case where both the equilibrium repayment rate and the equilibrium debt quantity of a low type are equal to zero, $r_1^\star(\lambda^l) = b_2^\star(\lambda^l) = 0$.

Possible deviations for the high type involve choices of debt, b_2, that differ from b_2^h.

The incentive constraint is

$$u(y_1 - b_1 + \beta b_2^h) + \delta u(y_2 - b_2^h) \geq u(y_1 - b_1 + \beta\theta_1^\star(1, b_2)b_2) + \delta u(y_2 - b_2) \;\forall\; b_2 \in [0, \infty).$$

In a separating equilibrium, the high type's debt is priced at β. When deviating to another debt level, the price equals $\beta\theta_1^\star(1, b_2)$, that is, it depends on lenders' off-equilibrium beliefs.

Possible deviations for the low type involve $r_1 = 1$ and/or $b_2 > 0$. The corresponding incentive constraints are

$$\begin{aligned} u(y_1) + \delta u(y_2) &\geq u(y_1 + \beta\theta_1^\star(0, b_2)b_2) + \delta u(y_2) \;\forall\; b_2 \in [0, \infty), \\ u(y_1) + \delta u(y_2) &\geq u(y_1 - b_1 + \beta\theta_1^\star(1, b_2)b_2) + \delta u(y_2) \;\forall\; b_2 \in [0, \infty). \end{aligned}$$

Since $\theta_1^\star(0, b_2) = 0$ (using the intuitive criterion) the first incentive constraint of the low type is always satisfied. The second incentive constraint requires that $\beta\theta_1^\star(1, b_2)b_2 \leq b_1$. In particular, evaluated at the high type's equilibrium choice, it requires (recall that $\theta_1^\star(1, b_2^h) = 1$)

$$b_2^h \leq b_1/\beta. \tag{4}$$

Condition (4) caps the loan that can be extended to the high type without inducing the low type to mimic. If the condition were violated, mimicking would generate a positive flow of funds to the low type in the first period without any associated cost in the second period. In order to prevent this, the high type country is not allowed to run a *current account deficit*.

A separating equilibrium thus satisfies $r_1^\star(\lambda^h) = 1$, $r_1^\star(\lambda^l) = 0$, $b_2^\star(\lambda^h) = b_2^h \in [0, b_1/\beta]$, $b_2^\star(\lambda^l) = 0$, $\theta_1^\star(1, b_2^h) = 1$, $\theta_1^\star(0, 0) = 0$, and $q_1^\star(1, b_2^h) = \beta$; it involves off-equilibrium beliefs $\theta_1^\star(0, b_2) = 0$ and $\theta_1^\star(1, b_2) \leq b_1/(\beta b_2)$ for all $b_2 \in [0, \infty)$.

The set of separating equilibria can be further pruned by using the intuitive criterion. Consider a candidate equilibrium with $b_2^h < b_1/\beta$. A deviation to b_1/β can only be associated with the off-equilibrium belief $\theta_1^\star(1, b_1/\beta) = 1$ as the low type would not gain from this deviation but the high type's utility is increasing in b_2 in the range $[0, b_1/\beta]$. Accordingly, $b_2^h = b_1/\beta$ is the unique separating equilibrium outcome.

Proposition 1. *In the endowment model featuring condition (L), a separating equilibrium exists. The only debt level consistent with the intuitive criterion is* $b_2^h = b_1/\beta$.

2.2.2 Pooling Equilibria

Since the high type always repays, any candidate pooling equilibrium necessarily features repayment in the first period. It also involves a quantity of debt issued, b_2^p, that is common for the two types. Lenders form the posterior belief $\theta_1^\star(1, b_2^p) = \theta$ and offer the equilibrium price, $q_1^\star(1, b_2^p)$, that satisfies condition (3), so for any $b_2^p > 0$, $q_1^\star(1, b_2^p) = \beta\theta$. An off-equilibrium choice of $r_1 = 0$ or $b_2 \neq b_2^p$ induces the posterior belief $\theta_1^\star(r_1, b_2)$ and a debt price $\beta\theta_1^\star(r_1, b_2)$.

Possible deviations for the high type involve choices of debt, b_2, that differ from b_2^p. The incentive constraint is

$$u(y_1 - b_1 + \beta\theta b_2^p) + \delta u(y_2 - b_2^p) \geq u(y_1 - b_1 + \beta\theta_1^\star(1, b_2)b_2) + \delta u(y_2 - b_2) \ \forall\ b_2 \in [0, \infty).$$

Possible deviations for the low type involve $r_1 = 0$ and/or $b_2 \neq b_2^p$. The corresponding incentive constraints are

$$\begin{aligned} u(y_1 - b_1 + \beta\theta b_2^p) + \delta u(y_2) &\geq u(y_1 - b_1 + \beta\theta_1^\star(1, b_2)b_2) + \delta u(y_2) \ \forall\ b_2 \in [0, \infty), \\ u(y_1 - b_1 + \beta\theta b_2^p) + \delta u(y_2) &\geq u(y_1 + \beta\theta_1^\star(0, b_2)b_2) + \delta u(y_2) \ \forall\ b_2 \in [0, \infty). \end{aligned}$$

The incentive constraint of the high type implies that a pooling equilibrium cannot exist if off-equilibrium beliefs are refined using the intuitive criterion. To see this, consider the following deviation: The high type issues $b_2^d \equiv \theta b_2^p - \epsilon$ where ϵ is strictly positive but infinitesimal, and the superscript "d" stands for "deviation." If the posterior of lenders associated with this deviation equals one, $\theta_1^\star(1, b_2^d) = 1$, such that $q_1^\star(1, b_2^d) = \beta$, then the deviation is profitable for the high type because

$$\begin{aligned} u(y_1 - b_1 + \beta b_2^d) + \delta u(y_2 - b_2^d) &> u(y_1 - b_1 + \beta(b_2^d + \epsilon)) + \delta u(y_2 - (b_2^d + \epsilon)/\theta) \\ &= u(y_1 - b_1 + \beta\theta b_2^p) + \delta u(y_2 - b_2^p), \end{aligned}$$

while it is not profitable for the low type (who only cares about current funds raised as she will not repay them) because

$$\beta\theta b_2^p = \beta(b_2^d + \epsilon) > \beta b_2^d.$$

Accordingly, the conjectured off-equilibrium beliefs (and no others) satisfy the intuitive criterion, the high type deviates, and the candidate pooling equilibrium does not exist. Since b_2^p was chosen arbitrarily no pooling equilibrium exists. Intuitively, lower debt, priced more favorably, keeps the funds raised in the first period nearly unchanged but reduces repayment in the second period. A reduction in future obligations is of greater value to the high than to the low type (because she repays more often), so the high type is willing to sacrifice more consumption now than the low type in order to achieve such a reduction.

Proposition 2. *In the endowment model featuring condition (L), no pooling equilibrium survives the intuitive criterion.*

As is common, the application of the Cho and Kreps (1987) intuitive criterion eliminates pooling equilibria. While this is attractive in terms of limiting equilibrium multiplicity, it also implies that Pareto superior equilibria may be eliminated. When θ is sufficiently high both types would be better off in a pooling rather than in the separating equilibrium described above, as they would receive more funds. In the working paper version of the current paper (e.g. Dellas and Niepelt, 2014) we used a different specification that allows pooling equilibria to survive and characterized the threshold value of θ above which pooling equilibria Pareto dominate the best separating equilibrium. But as the emphasis of our paper is on signalling one's creditworthiness when the creditors have serious doubts about it (a low θ environment), the elimination of pooling equilibria via the intuitive criterion carries no cost.

2.3 Costly signalling

In the analysis so far, the high type does not face a "meaningful" choice between default and repayment: She always chooses to repay maturing debt because the immediate cost of default exceeds the cost of debt repayment (due to assumption (L)). But what if the amount of maturing debt was larger than the cost suffered in case of default (that is, $b_1 > \lambda^h y_1$)? Would there be any reasons for the country to still repay? The extant policy debate has suggested that a creditworthy borrower might choose to repay in order to signal her type and face improved terms in new borrowing.

In order to accommodate this possibility we modify condition (L) to

$$0 = \lambda^l < \lambda^h < b_1/y_1. \tag{L'}$$

Condition (L') states that the immediate cost of default at date $t = 1$ falls short of the amount of debt due in that period. The question is under what conditions a high type nevertheless chooses to repay rather than default in this case.

Under condition (L') default no longer identifies the low type, that is, $\theta_1^\star(0, b_2)$ does not have to be zero. Nevertheless, it is still the case that in a separating equilibrium a high type repays while a low type defaults and issues $b_2^l = 0$. The debt issued by the high type, b_2^h, must satisfy the incentive constraints analyzed previously as well as two additional incentive constraints for the high type, namely,

$$\begin{aligned} b_2^h &\leq y_2\lambda^h, \\ u(y_1 - b_1 + \beta b_2^h) + \delta u(y_2 - b_2^h) &\geq u(y_1(1-\lambda^h) + \beta\theta_1^\star(0, b_2)b_2) + \delta u(y_2 - b_2) \; \forall \; b_2 \in [0, y_2\lambda^h]. \end{aligned}$$

The first constraint guarantees repayment in the second period. The second states that the high type must not profit from defaulting and choosing some quantity b_2.

The crucial difference from the case analyzed earlier with $\lambda^h = \infty$ is that the second constraint imposes a lower bound on b_2^h because the high type must be induced not to default. Suppose, for instance, that $\theta_1^\star(0, b_2) = 0$ such that the high type would choose $b_2 = 0$ when deviating. In this case, an equilibrium loan size $\beta b_2^h \leq b_1 - \lambda^h y_1$ would induce the high type to default. To induce separation, the equilibrium loan size therefore has to be strictly greater than $b_1 - \lambda^h y_1$. A more "positive" posterior ($\theta_1^\star(0, b_2) > 0$ for some b_2) would improve the value of deviating for a high type and therefore imply an even higher lower bound for b_2^h. Consequently, in a separating equilibrium, the level of financing can be neither too high (otherwise the low type mimics) nor too low (otherwise the high type defaults too).

A separating equilibrium exists when y_2/y_1 is sufficiently large and b_1 not too high. Assuming that separating equilibria exist, the intuitive criterion can be used, as before, to eliminate all separating equilibrium outcomes but one, namely $b_2^h = b_1/\beta$. Similarly, for the case of interest that involves signalling, that is repayment by the high type, the intuitive criterion can be used to eliminate all pooling equilibria.

2.4 Frictions and Consumption Backloading

How do the two frictions, namely lack of commitment and asymmetric information, jointly shape the equilibrium profile of consumption? Do they tilt consumption in the same or in opposite directions?

To answer these questions, we first consider the case of $b_1 < \lambda^h y_1$ analyzed in subsection 2.2. If lack of commitment constitutes the only friction (that is, if information is complete), b_2 is capped by $\lambda^h y_2$ and the slope of the consumption profile of the high type is given by

$$\frac{y_2(1-\lambda^h)}{y_1 - b_1 + \beta\lambda^h y_2}. \tag{5}$$

Incomplete information does not affect this cap but introduces other restrictions on b_2. In particular, in a separating equilibrium, the selection constraint of the low type imposes the additional cap $b_2 \leq b_1/\beta$, in order to prevent mimicking. Incomplete information is of consequence if $b_1/\beta < \lambda^h y_2$, in which case the consumption profile is given by

$$\frac{y_2 - b_1/\beta}{y_1}, \tag{6}$$

which is steeper than that in (5). Incomplete information thus amplifies the consumption backloading induced by limited commitment.

Consider next the case of $b_1 > \lambda^h y_1$; this corresponds to the situation analyzed in subsection 2.3. Under complete information, the high type defaults in the first period, thus gaining an extra income of $b_1 - \lambda^h y_1$ relative to the case of no default. If, despite this higher income the borrowing constraint remains binding, then his consumption profile is more backward tilted relative to that under full commitment (the slope is given by (5) with $y_1 - b_1$ replaced by $y_1(1-\lambda^h)$). Under incomplete information, the high type signals her type by repaying and the no-mimicking constraint imposes a cap on loan size as discussed above. The slope of the consumption profile, (6), exceeds the slope in the one-friction case.

One can use these consumption ratios to examine the role played by b_1 and λ^h in the determination of the relative contribution of the two frictions to consumption backloading. Consider first the case of $b_1 < \lambda^h y_1$. In the separating equilibrium, the relative consumption profile is given by the ratio of the expressions in (6) and (5),

$$\frac{y_2 - b_1/\beta}{y_1} \frac{y_1 - b_1 + \beta\lambda^h y_2}{y_2(1-\lambda^h)} > 1.$$

This relative consumption profile is decreasing in b_1 and increasing in λ^h. That is, a higher level of initial debt lowers the relative contribution of incomplete information to consumption backloading while higher default costs raise it. The latter property is intuitive as more severe sanctions ameliorate the limited commitment problem.

Similar patterns obtain when $b_1 > \lambda^h y_1$. Again, higher default costs always raise the relative contribution of incomplete information to consumption backloading. Moreover, a higher b_1 reduces the relative contribution of incomplete information. As we will see in the next section, the same mechanisms operate in the version of our model that contains investment, whose level can be used to signal the borrower's type.[9]

3 Investment

We now introduce investment in the first period and analyze its role as a signalling device. Output in the second period is given by $y_2 + f(I_1)$ where $f(\cdot)$ denotes a decreasing returns to scale production function and I_1 is investment. We interpret investment broadly: It might represent physical investment or investment in institutions and reforms that increase future productivity.

In models with complete information in which default triggers concurrent output losses that also afflict the fruits of investment (such as Obstfeld and Rogoff, 1996, 6.2.1.3), investment alleviates the borrowing constraint. In our model, investment alleviates the

[9]In our framework, default costs take the form of concurrent output or collateral loss. In the one friction version, such a model features a negative relation between current investment and the probability of future default. In models where default costs take the form of exclusion from credit markets, this relation may be ambiguous as investment changes both the borrower's intertemporal opportunities set and the value of autarky. Such models therefore may exhibit different properties with regard to the effects of the two frictions on the degree of consumption backloading. We are grateful to a referee for pointing this out.

borrowing constraint through a different mechanism, namely, by providing information to creditors that the cost of future default is high. In order to highlight this informational role we completely abstract from the traditional collateral role by assuming that produced second-period output, $f(I_1)$, is *not* subject to default costs,[10] and we focus directly on separating equilibria. In any case, application of the intuitive criterion eliminates pooling equilibria, as in the previous section.[11]

In addition to the default decision and the choice of the level of debt, the borrower now also chooses the level of investment. This requires—as in models where investment enhances the sovereign's collateral—that a country can commit to a level of investment, or, to a specific reform before the loan is disbursed.[12] In all other respects, the timing assumptions and definition of equilibrium are the same as in the endowment model analyzed in section 2. We also maintain the assumptions about default costs, namely $0 = \lambda^l < \lambda^h = \infty$. Recall that this assumption implies that in the absence of incomplete information, the high type's level of borrowing and investment are first best.

We will focus directly on the best separating equilibrium from the perspective of the high type because the intuitive criterion again rules out other equilibria. In this separating equilibrium, the high type chooses to repay, to issue the quantity of debt b_2^h, and to invest the amount I_1^h; the low type defaults, issues $b_2^l = 0$, and invests I_1^l, her preferred level of investment conditional on default and $b_2^l = 0$. The maximization problem is to find the best choices of b_2^h and I_1^h that are incentive compatible.

Forming the Lagrangean of the maximization problem subject to incentive compatibility,

$$\mathcal{L} = u(c_1^h) + \delta u(c_2^h) + \mu \left\{ u(c_1^l) + \delta u(c_2^l) - u(c_1^h) - \delta u\left(y_2 + f(I_1^h)\right) \right\},$$

μ denotes the non-negative multiplier associated with the selection constraint of the low type. The variables c_1^h, c_2^h, c_1^l, and c_2^l denote the first- and second-period equilibrium

[10] Changing this assumption and letting default costs also apply to produced output, as in Obstfeld and Rogoff (1996), makes no substantive difference for our results.

[11] The high type would always find it profitable to credibly signal her type by issuing a smaller quantity of debt or investing a higher amount than the candidate equilibrium outcomes.

[12] Making funding conditional on certain debtor actions is a common theme in financial markets. In the sovereign debt context IMF conditionality constitutes a prime example.

consumption levels of the high and low type, respectively,

$$\begin{aligned} c_1^h &\equiv y_1 - b_1 + \beta b_2^h - I_1^h, \\ c_2^h &\equiv y_2 - b_2^h + f(I_1^h), \\ c_1^l &\equiv y_1 - I_1^l, \\ c_2^l &\equiv y_2 + f(I_1^l). \end{aligned}$$

The selection constraint states that a low type is better off defaulting, receiving no new loans and freely choosing an investment level I_1^l, rather than mimicking a high type in the first period and defaulting in the second period; note that mimicking implies that the low type invests the amount I_1^h rather than her preferred I_1^l.

In addition to the complementary slackness condition,

$$\mu \left\{ u(c_1^l) + \delta u(c_2^l) - u(c_1^h) - \delta u\left(y_2 + f(I_1^h)\right) \right\} = 0,$$

we have the following first-order conditions:

$$\begin{aligned} \beta u'(c_1^h)(1-\mu) &= \delta u'(c_2^h), \\ u'(c_1^h)(1-\mu) &= \delta f'(I_1^h) \left\{ u'(c_2^h) - \mu u'(y_2 + f(I_1^h)) \right\}. \end{aligned}$$

The first condition describes the optimal choice of b_2^h. With incomplete information ($\mu > 0$) the high type is borrowing constrained and her consumption profile is steeper than what it would have been in the absence of incomplete information. The fact that marginal utility is strictly positive implies $\mu < 1$.

The second condition describes the optimal choice of I_1^h. We can rewrite it as

$$\begin{aligned} u'(c_1^h) &= \delta f'(I_1^h) u'(c_2^h) \, \frac{1}{1-\mu} \frac{u'(c_2^h) - \mu u'(y_2 + f(I_1^h))}{u'(c_2^h)} \\ &= \delta f'(I_1^h) u'(c_2^h) \, \frac{1-\mu\gamma}{1-\mu} \\ \Rightarrow \quad u'(c_1^h) &> \delta f'(I_1^h) u'(c_2^h), \end{aligned}$$

where $\gamma \equiv u'(y_2 + f(I_1^h))/u'(c_2^h) < 1$ because a mimicking low type consumes more in the second period than a high type as only the latter repays debt.

As a consequence, a mimicking low type values future income less than the high type. Since both consume the same amount in the first period, the mimicking low type's preferred investment level, for any level of debt, is smaller than that of the high type. This fact can be exploited to impose a high investment requirement which helps relax the selection constraint and allow for the issuance of more debt than in the case where investment does not serve as a signal. The wedge in the first-order condition for I_1^h reflects the benefit from relaxing the selection constraint and resembles the wedge from an investment subsidy at rate $(1-\mu\gamma)/(1-\mu) > 1$.

Combining the first-order conditions we have $\beta f'(I_1^h) = (1-\mu\gamma)^{-1} > 1$. The fact that the marginal product at the first-best investment level equals β^{-1} implies that the investment level of the high type in the separating equilibrium is strictly smaller than in first best. The equilibrium loan size, b_2^h, also falls short of its first-best level.[13]

These results are summarized in the following proposition.

Proposition 3. *In the model with investment and a binding selection constraint ($\mu > 0$), investment of the high type is distorted upwards conditional on loan size. The level of investment and borrowing are smaller than their corresponding first-best levels.*

Figure 1 offers a graphical illustration of the properties of equilibrium in (b_2^h, I_1^h) space. The solid curve gives the level of investment that the high type would prefer, for a given level of debt b_2^h, in the absence of a signalling motive. It is upward sloping because preferred investment increases in the level of funding. Also, since the curve gives the preferred I_1^h conditional on b_2^h, the high type's indifference curves are vertical when they intersect it. The figure depicts one such indifference curve—the dashed curve—through point B.

The demarcation line between the shaded and non-shaded areas in figure 1 is the locus of (b_2^h, I_1^h) combinations that satisfy the selection constraint of the low type with equality. That is, the demarcation line represents the indifference curve of a mimicking low type.

[13] Let a "$\diamond$" denote first-best levels of the high type. Using the Euler equation in the first best and in equilibrium as well as the fact that $I_1^h < I_1^\diamond$ we have $\frac{u'(c_1^\diamond)}{\delta u'(c_2^\diamond)} = f'(I^\diamond) < f'(I_1^h) < \frac{u'(c_1^h)}{\delta u'(c_2^h)}$. If b_2^h exceeded $b_2^\diamond$ this would imply $c_1^h > c_1^\diamond$ and $c_2^h < c_2^\diamond$, leading to a contradiction.

All debt-investment combinations in the shaded area to the left of the demarcation line are incentive compatible. As we showed earlier, the mimicking low type prefers a lower level of investment than the high type, for any level of debt. Consequently, the demarcation line is vertical at a point that lies below the solid curve (namely at point A), and the slope of the demarcation line at point B thus is positive and finite.

An upward move away from B along the demarcation line represents over-investment and leaves the mimicking low type indifferent but increases the welfare of the high type. Point C indicates the separating equilibrium. At this point, the demarcation line is tangent to an indifference curve of the high type.

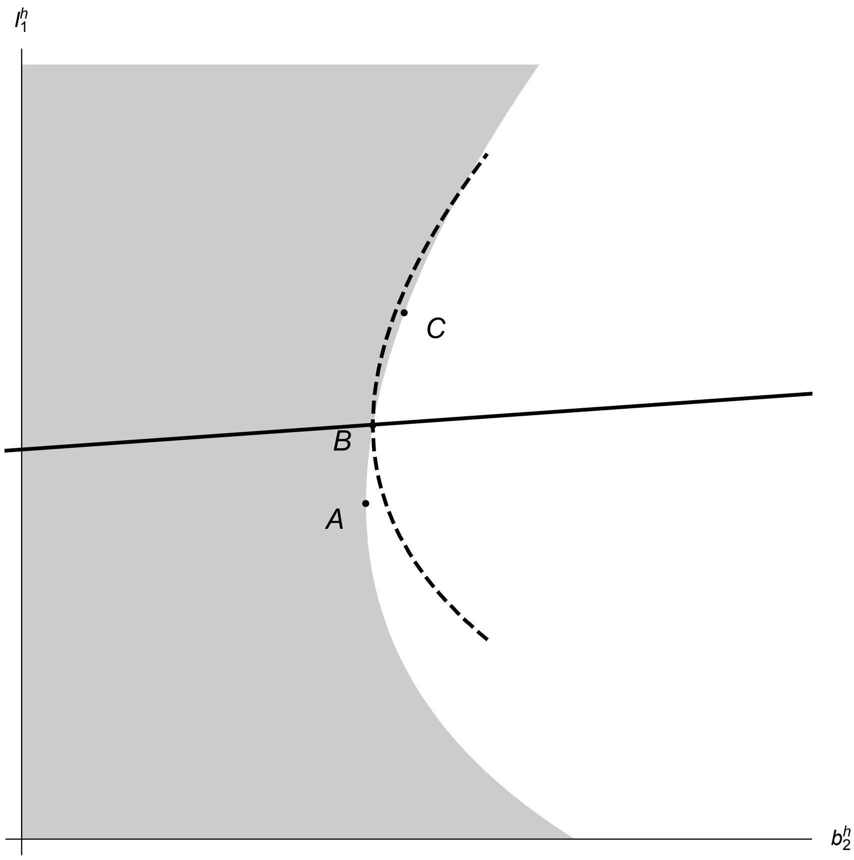

Figure 1: *Separating equilibrium with contractible investment.*

Note: Point C corresponds to the separating equilibrium and point B corresponds to the separating equilibrium when investment is not contractible. The demarcation line between the shaded and non-shaded areas represents the selection constraint of the low type.

Although the move from point B to point C in figure 1 improves the high type's welfare, it *lowers* her first-period consumption. To see this, note that the slope of the selection constraint at point B exceeds β,[14]

$$\frac{dI_1^h}{db_2^h}|_{\text{sel},B} = \frac{\beta}{1 - \frac{u'(y_2+f(I_1^h))}{u'(y_2-b_2^h+f(I_1^h))}} > \beta.$$

That is, on the segment from point B to point C, each extra unit of new debt issued (which generates β units of current funds) requires the additional investment of more than β units. Consequently, the extra funds do not bring about higher consumption in the first period as consumption is lower at C than at B.[15]

How does the use of investment as a tool to mitigate the information problem affect the slope of the consumption profile relative to the endowment case? Proposition 4 states that the profile becomes steeper, that is, the use of investment further reduces consumption smoothing.[16]

Proposition 4. *The separating equilibrium in the model with investment and $\mu > 0$ involves more backloading of consumption than the separating equilibrium in the endowment model.*

The proof is as follows. In the endowment economy analyzed in section 2, the high type receives funds $\beta b_2^h = b_1$. Hence,

$$\frac{c_2^h}{c_1^h} = \frac{y_2 - b_1/\beta}{y_1}. \tag{7}$$

[14]The slope of the selection constraint equals

$$\frac{dI_1^h}{db_2^h}|_{\text{sel}} = \frac{\beta}{1 - \delta f'(I_1^h)\frac{u'(y_2+f(I_1^h))}{u'(y_1-b_1+\beta b_2^h-I_1^h)}},$$

while investment at point B satisfies the first-order condition for investment,

$$u'(y_1 - b_1 + \beta b_2^h - I_1^h) = \delta f'(I_1^h)u'(y_2 - b_2^h + f(I_1^h)).$$

Substituting the latter into the former condition yields the result.

[15]To the right of point B and the left of point C along the selection constraint, the slope $dI_1^h/db_2^h|_{\text{sel}}$ decreases but it is bounded from below by β.

[16]We can also repeat the analysis of subsection 2.4 to compare the contribution of the two frictions. Again, due to the fact that the presence/absence of the informational friction does not impact on the loan cap arising from limited commitment, the over investment induced by incomplete information simply adds a further backward tilt to the consumption profile.

Since the high type is borrowing constrained, this ratio is higher than the corresponding ratio in the first best so there is less consumption smoothing than in the first best.

With investment, the amount of new funds obtained in the first period can be written as $\beta b_2^h = b_1 + sI_1^h$, where s is a scalar. The consumption ratio c_2^h/c_1^h is then given by

$$\frac{c_2^h}{c_1^h} = \frac{y_2 - b_2^h + f(I_1^h)}{y_1 - b_1 + \beta b_2^h - I_1^h} = \frac{y_2 - b_1/\beta + f(I_1^h) - sI_1^h/\beta}{y_1 + (s-1)I_1^h}. \tag{8}$$

Comparing expressions (7) and (8), we see that a sufficient condition for the consumption profile to be steeper in the model with investment, is that $0 < s < 1$.[17] The proof that this condition is satisfied is as follows. If s were unity (or higher), the selection constraint of the low type would be violated: first- and second-period consumption of a mimicking low type would be y_1 (or higher) and $y_2 + f(I_1^h)$, respectively. These levels exceed consumption when not mimicking, $y_1 - I_1^l$ and $y_2 + f(I_1^l)$, respectively. So the loan has to be less favorable ($s < 1$) in order to support separation. If, on the other hand, s were zero the selection constraint of the low type would be slack: a low type's utility would be $u(y_1 - I_1^l) + u(y_2 + f(I_1^l))$ when not mimicking and $u(y_1 - I_1^h) + u(y_2 + f(I_1^h))$ when mimicking. The former is larger because I_1^l represents the conditionally optimal investment level. So s could be increased ($s > 0$). The separating equilibrium with the maximal incentive compatible funding level thus satisfies $0 < s < 1$.

4 Application to the Greek Debt Crisis

Does incomplete information about a government's creditworthiness play an important role in sovereign debt markets? Statements by German officials about the need for Greece to accept austerity (rather than default) as a means of signalling its creditworthiness, as expressed for example by Finance minister Schäuble or Chancellor Merkel,[18] indicate that it certainly played an important role in the Greek debt crisis.

But in addition to the official proclamations, the data characterizing the credit relationship between Greece and her official creditors during the crisis seem consistent with

[17] If $0 < s < 1$ then (8) has a smaller denominator and a larger numerator than (7). The latter is due to the fact that $f(I_1^h) \geq f'(I_1^h)I_1^h > (1/\beta)I_1^h > sI_1^h/\beta$ because $I_1^h < I^\diamond$.

[18] "…austerity measures are adopted in order to send a very important signal …" (*The Wall Street Journal*, 12 July 2011).

the signalling model developed in this paper. In contrast, this data seems to pose a challenge to the baseline, complete information sovereign debt model.

In February 2015, Syriza, a party that had run a campaign based on the threat to default on the country's external debt unless the country were granted substantial debt relief, won national elections and formed a government. Default risk premia in the secondary market for Greek debt shot up. For instance, the rate on 10-year Greek bonds on the secondary market rose from 5.8% in July 2014 to 14% in July 2015.

Nonetheless, although no debt relief was granted, Greece did not default. And after an acrimonious, lengthy process, the government agreed to a new loan contract with the creditors. The main features of this contract were as follows: First, the amount of funds supplied was limited (relative to those in previous arrangements), and as a result, it involved very ambitious budget surplus targets, namely, surpluses of 0.5%, 1.75%, and 3.5% for 2016, 2017 and 2018, respectively, in spite of the fact that macroeconomic conditions in Greece were worsening (the growth rate had turned strongly negative after having been positive at the end of 2014). Second, the loan was made conditional on the implementation of stringent reforms that had until then proved elusive: the loan was divided up in tranches each of which was to be disbursed only after the country had satisfied specific reform criteria. And third, the effective interest rate on the new loans declined relative to the earlier loan arrangements, even after accounting for the lower cost of funds for creditors. Moreover, default risk premia on Greek bonds on the secondary market also declined significantly.

These patterns are consistent with our analysis under the assumption that Syriza was pretending to be a low type in order to maximize electoral support but its type was high. Before Syriza committed to the stringent conditions (austerity) of the new financing agreement, default risk premia shot up. Following acceptance of the agreement (which in our view represented a signal of being a high type), rates went down. More importantly, the supply of funds decreased. It is the latter feature that differentiates our model from the standard, complete information model. In that model, loan size and interest rates are negatively related. In the separating equilibrium of our model, they are positively related.

5 Conclusions

Information frictions may lead creditors to doubt a creditworthy government's commitment to honor its debt obligations. In such a situation, the government could either abstain from trying to change the beliefs of the creditors; or, try to communicate its type to the creditors by taking appropriate, costly actions (a separating equilibrium).

Importantly, even when adopting the latter strategy, a creditworthy government remains subject to credit rationing, because this deters mimicking by a low type. We have shown that the degree of rationing can be reduced if the sovereign is prepared to use "excessive" investment or reforms as a signal. But while the use of high investment as a signal affords more funds this does not translate into higher national consumption: on the contrary, greater funding is associated with a sacrifice of current for future consumption. We believe that such belt tightening in response to doubts about debt repayment represents a useful way to think about "austerity."

We have also argued that our framework is better suited than the standard sovereign debt model to shed light on the credit relationship between Greece and her foreign creditors after the 2015 election. Favorable interest rates, debt conditionality, reforms that depress current consumption and debt rationing can be understood as the response to profound uncertainty about the Greek government's creditworthiness.

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References

Arellano, C. (2008). 'Default risk and income fluctuations in emerging economies', *American Economic Review*, vol. 98(3), pp. 690–712.

Balke, N.L. and Ravn, M.O. (2016). 'Time-consistent fiscal policy in a debt crisis', CEPR, London.

Bester, H. (1985). 'Screening vs. rationing in credit markets with imperfect information', *American Economic Review*, vol. 75(4), pp. 850–855.

Canzoneri, M.B. (1985). 'Monetary policy games and the role of private information', *American Economic Review*, vol. 75(5), pp. 1056–1070.

Cho, I.K. and Kreps, D.M. (1987). 'Signaling games and stable equilibria', *Quarterly Journal of Economics*, vol. 102(2), pp. 179–221.

Cole, H.L., Dow, J. and English, W.B. (1995). 'Default, settlement, and signalling: Lending resumption in a reputational model of sovereign debt', *International Economic Review*, vol. 36(2), pp. 365–385.

Conesa, J.C., Kehoe, T.J. and Ruhl, K.J. (2016). 'Optimal austerity', Unpublished, Federal Reserve Bank of Minneapolis.

Dellas, H. and Niepelt, D. (2014). 'Austerity', CEPR.

D'Erasmo, P. (2011). 'Government reputation and debt repayment in emerging economies', University of Maryland, College Park.

Dovis, A. (2019). 'Efficient sovereign default', *Review of Economic Studies*, vol. 86(1), pp. 282–312.

Eaton, J. and Gersovitz, M. (1981). 'Debt with potential repudiation: Theoretical and empirical analysis', *Review of Economic Studies*, vol. 48(2), pp. 289–309.

Gibert, A. (2016). 'The signaling role of fiscal austerity', DIW, Berlin.

Green, E.J. and Porter, R.H. (1984). 'Noncooperative collusion under imperfect price information', *Econometrica*, vol. 52(1), pp. 87–100.

Kreps, D.M. and Sobel, J. (1994). 'Signalling', in (R. J. Aumann and S. Hart, eds.), *Handbook of Game Theory*, pp. 849–867, vol. 2, chap. 25, Amsterdam: North-Holland.

Obstfeld, M. and Rogoff, K. (1996). *Foundations of International Macroeconomics*, Cambridge, Massachusetts: MIT Press.

Perez, D.J. (2017). 'Sovereign debt maturity structure under asymmetric information', *Journal of International Economics*, vol. 108, pp. 243–259.

Phan, T. (2017). 'A model of sovereign debt with private information', *Journal of Economic Dynamics and Control*, vol. 83, pp. 1–17.

Sandleris, G. (2008). 'Sovereign defaults: Information, investment and credit', *Journal of International Economics*, vol. 76(2), pp. 267–275.