

Essays in Economics

by

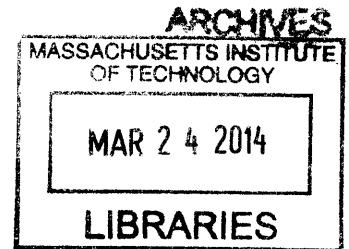
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Abstract

In the first chapter, I explore the role of coordination problems and self-fulfilling beliefs as drivers of sovereign default risk. I employ global-game techniques to induce a unique equilibrium. Along the unique equilibrium, I show how the equilibrium default risk can be decomposed in a solvency-risk component and a coordination-risk component. I then study how fiscal policy can be effective in managing the risk of coordination and I characterise how the shape of the optimal policy is affected by the presence of this risk. I finally show that making the deficit contingent on interest rate movements is more effective in managing default risk than using non-contingent fiscal targets.

The second chapter (co-authored with Emine Boz) studies a model in which a government issues bonds to fund a project whose return is unknown to private investors. The government has access to a technology that allows it to manipulate the mean of a public signal. Even though investors fully internalize the manipulation technology - which makes it hard for the government to “fool” them - and manipulation is costly, we show that it occurs in equilibrium. Our extensions reveal that higher transparency leads to weaker manipulation incentives, news about a high probability of manipulation significantly lowers the bond price, and that manipulating private signals leads to similar outcomes as manipulating public signals.

The third chapter investigates the relationship between trust and firm activity. Using Italian micro-data, I find that trust affects labour productivity, although larger firms do not appear to benefit more from higher levels of trust. This is in contrast with evidence from cross-country studies, and suggests the cross-country correlation may be spurious. I do not find that trust matters to the main capital owner’s decision to delegate control of the firm to either relatives or professional managers, nor that it makes a difference to the firm’s choice of hiring accountants and auditors.

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Andrej, this accomplishment is as much yours as it is mine.

Basel, February 4th, 2014

to Andrej, love of my life

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Chapter 1

Managing default risk

The ongoing European debt crisis highlights the role of coordination problems and self-fulfilling beliefs as drivers of sovereign default risk. For example, despite having introduced a raft of austerity measures aimed at allaying market fears to reduce funding costs, countries like Spain and Italy still face high borrowing costs reflected in large spreads over German interest rates, suggesting that market panic is still widespread. One could also legitimately wonder whether the onset of the crisis was due to worsening fundamentals or the self-fulfillment of bleak expectations associated with the global financial crisis that has resulted in the Great Recession. Prior to 2008, the average debt-to-GDP ratio in the five troubled Euro area economies - Portugal, Ireland, Greece, Spain and Italy - had been consistently falling, not rising, so fundamentals had been improving. Even in beleaguered Greece, debt ratios had been stable, albeit high, before the crisis hit. And even if the deadly combination of low growth, bank bailouts, and rising interest rates did push debt ratios up during the crisis, De Grauwe and Ji (2012) find that this deterioration only accounts for a fraction of the surge in the spreads of Portugal, Ireland, Greece and Spain between 2010 and 2011. They conclude that a significant share of the increase in spreads is accounted for by negative market sentiments. Such sentiments seem to loom very large in the outlooks and recommendations of policymakers across the world. In April 2012, the International Monetary Fund's Global Financial Stability Report expressed concern over the "risk that adverse self-fulfilling shifts in market sentiment could rapidly push fragile sovereigns into a bad equilibrium of rising yields" (pp. 17), and not for the first time.¹ The European Central Bank seems as concerned as the Fund, to the point that it has recently abandoned its historical resistance

¹On the 21st of December 2011, Olivier Blanchard, the Fund's Economic Counsellor, publicly expressed the view that "the world economy is pregnant with multiple equilibria". See <http://blog-imfdirect.imf.org/2011/12/21/2011-in-review-four-hard-truths>.

to acting as a lender of the last resort for governments. In the speech announcing the introduction of outright monetary transactions on September 6th, 2012, the ECB President Mario Draghi justified the new policy with a need to help the large parts of the Euro area who find themselves in a bad equilibrium. He openly decried pessimistic self-fulfilling expectations that threaten the union as a whole (Draghi, 2012).

Concerned policymakers' recommendations and decisions thus appear to be informed by models with multiple equilibria, which help to conceptualise the dual nature of default risk. On the one hand, sovereigns may default because fundamentals such as the debt-to-GDP ratio are bad (solvency risk). On the other hand, governments may find themselves in situations where fundamentals are not too bad, and yet default happens because the markets panic and yields sky-rocket (coordination risk). Had markets not coordinated on expecting a bad outcome, the same fundamentals would have sustained lower yields and no default. For instance, had Greece had a better debt to GDP ratio, it may not have been as vulnerable to the change in confidence which followed the Goldman Sachs debt-swap scandal in early 2010.² The Greek government may have been solvent and yet illiquid.

Models with multiple equilibria suggest that countries have two options to deal with default risk. First, they can improve their fundamentals. Fiscal consolidations that bring about reductions in the level of debt make sovereigns less vulnerable to both solvency and coordination risk. In addition, when high coordination risk results in high funding costs or the outright inability to borrow from financial markets, governments have the option of turning to a lender of the last resort (such as the no-longer-reluctant ECB) to borrow at reasonable rates. Indeed, the policy debate around the European debt crisis has been dominated by precisely these issues, a need for fiscal consolidation and for reform of the Euro zone institutional architecture to broaden the mandate of the central bank. Fiscal consolidations are however costly, especially in countries where a large fraction of government spending accrues to social protection programs and fiscal pressure is already high. To the extent that fiscal consolidation comes as a requirement for central banks bailouts, appealing to the lender of the last resort may not be a palatable option, either, and it may carry reputational losses, for good measure.

This paper investigates whether governments can actively manage the risk of self-fulfilling market panics by appropriately tailoring fiscal policy. Specifically, I am going to address two questions:

²See, inter alia, <http://www.bloomberg.com/apps/news?pid=newsarchive&sid=a5MJFT2dMyIU&pos=1>.

- (1) Can fiscal policy be used to manage the risk of coordination, and if so, how?
- (2) How does coordination risk management affect the shape of the optimal policy?

In order to address these questions, I build on models with multiple equilibria so as to generate coordination risk (e.g. Calvo (1988)). Since I am interested in studying a policy question, I employ the global games techniques developed by Morris and Shin (1998, 2001, 2003) to induce a unique equilibrium. Along the unique equilibrium, I de-compose default risk into a solvency-risk component and a coordination-risk component. I then study how fiscal policy can be effective in managing the risk of coordination and I characterise how the shape of the optimal policy is affected by the presence of this risk.

I adopt a two-period model with two types of agents, a government and a continuum of small risk-neutral households with homogenous endowments. Households make consumption, labour and savings decisions, while the government chooses borrowing and taxes. The government borrows by issuing a one period pure discount bond whose price is endogenously determined. The bond is risky because the government has the option to default on its liabilities. Defaulting is costly and taxes generate distortions.

To “globalise” the model, I take the default cost to be the fundamental of the economy. The fundamental is not common knowledge.³ While households and the government share a common normal prior, households have private information that underpins their trades in the financial market. As a result, the rational expectations equilibrium bond price aggregates information, a common feature of the literature on global games with endogenous prices (e.g. Angeletos and Werning (2006), Hellwig, Mukherji, and Tsyvinski (2006), Tarashev (2007)). Specifically, the bond price conveys a noisy public signal about the cost of default. Consistent with practical definitions widely employed in the financial news, changes in the price can be thus interpreted as changes in market sentiments, a higher value of the signal tells the government that the market has become more optimistic and it is willing to fund borrowing at a lower cost. Under this interpretation of market sentiments as a noisy signal conveyed by prices, sentiments volatility has two drivers. Both higher values of the fundamental and higher values of the noise shock translate in a higher price signal, which amounts to a more bullish market. As a result, volatility in market outlooks is underpinned by both fundamental and non-fundamental volatility.

³The default cost parameterises the strength of the government’s commitment problem. As such, it is a natural candidate for the source of heterogeneity, as it is likely much more difficult to estimate than other economic fundamentals such as output or government spending.

In this framework, a government responds to market changes by conditioning borrowing on the bond price.

I show that by adopting cost-contingent fiscal targets, governments can affect the distribution of default risk across different values of the interest rate. For instance, selecting an upward-sloping borrowing schedule rather than an inelastic schedule (i.e. a constant borrowing level) enables the planner to reduce default risk when interest rates are high and to increase it when they are low. The government achieves this different risk distribution by affecting the composition of default risk, and specifically, by altering the distribution of coordination risk across values of the equilibrium interest rate.

The reason why government are at all able to affect coordination risk is that the incentive to default increases with government liabilities. Households face a coordination problem whereby it pays for them to demand a high return on government debt when they anticipate that everyone else is also demanding high returns, since this pushes the equilibrium interest rate high and increases the risk of default via higher liabilities. By selecting cost-contingent borrowing schedules, governments can lessen the correlation between the interest rate and liabilities, and thus weaken the correlation between interest rates and default risk.

The policy required to achieve the optimal risk decomposition is non-monotonic in interest rates. When interest rates are low, a deterioration in market sentiments leading to higher funding costs reins in government borrowing and increases the tax rate. The market thus works as a disciplining device for sovereign borrowers. When interest rates are high, however, this mechanism ceases to work. During confidence crises, higher rates cause governments to take out more debt. This is because when the market is very pessimistic, the likelihood of default is less sensitive to the government's choice of borrowing, and the costs of default do not depend on government liabilities.

Managing coordination risk by committing to cost-contingent fiscal targets turns out to be an additional policy tool for sovereign borrowers facing confidence crises. Compared to a government that announces a target level for borrowing, a government who can commit to a cost-contingent schedule reduces both its borrowing costs and default risk over a range of market sentiments. This suggests that troubled Euro area economies who cannot rely on debt monetisation as a debt management strategy ought to consider adopting contingent fiscal targets as an additional self-reliant instrument to relieve market pressures.

The model developed in this paper builds on research on debt crises pioneered by Calvo (1988) and expanded by Alesina et al. (1990), Giavazzi and Pagano (1990)

and more recently by Cole and Kehoe (2000). Debt is held domestically, unlike in the literature on sovereign borrowing exemplified by Eaton and Gersovitz (1981). The key innovation of the paper is the introduction of dispersed information, which makes it possible to overcome the problem of multiplicity and allow governments to commit to cost-contingent borrowing targets.

The paper is also closely related to the literature on global games with endogenous prices. Angeletos and Werning (2006) obtain a multiplicity result in a model with endogenous asset prices. In their model, the payoff from holding the financial asset is determined in a separate coordination game that happens after trading in market. In this paper, however, the coordination game is embedded in the financial market instead, so that choosing not to trade is equivalent to choosing to attack the regime. This feature makes it closer to Hellwig et al. (2006). They present a model of currency crises with an endogenous price to prove that when public information is endogenous, equilibrium multiplicity may be restored in a global-games framework provided agents are sufficiently well-informed. I build on their analysis by introducing explicit micro-foundations.

Morris and Shin (2004) have studied the problem of a solvent borrower that may be forced into default by illiquidity arising from a coordination failure. They do not, however, consider endogenous prices, and their model is better suited to study default risk on corporate rather than on sovereign debt.

The rest of the paper is organised as follows. Section 1.1 introduces the model. Sections 1.2 and 1.2.1 define and characterise the equilibrium, respectively. In Section 1.2.2, I study common knowledge benchmarks to introduce the decomposition of default risk into a solvency component and a coordination component. In Section 1.3 I present results from numerical simulations. Section 1.4 discusses cost-contingent borrowing targets. Finally, Section 1.5 offers concluding remarks.

1.1 The basic model

There is a continuum of households, indexed by $i \in [0, 1]$. Each household is endowed with private information about the economy. Households make consumption and saving decisions. In addition, the economy is inhabited by a benevolent government who chooses a mix of taxes and borrowing to finance (exogenous) government consumption. The government borrows by issuing a one period discount bond with unitary face value that trades at price p . The government lacks commitment, thus making debt risky. Finally, the government does not have private information regarding the state of the economy, so there are two types of informational asymmetries

in this model: across households and between households and the government.

Due to the technical difficulty of studying global games in infinite horizon economies, I consider two periods. Nonetheless, for my numerical simulations I derive the government's second period value function as the value function of a benevolent dictator in an infinite horizon economy with commitment, thereby ensuring sensible numerical results for the tax rates and borrowing levels.

In the first period, households receive information about the state of the economy. Then the financial market opens: households post demand functions for bonds contingent on the price; the government posts a supply function for bonds, also conditional on the price. The government commits to the schedule it announces, so it cannot renege on it after observing the distribution of bond demand schedules submitted by households. After the financial market closes, the bond price is determined to clear the market for funds. Next, the labour market opens: households work, they receive income, they pay taxes and consume. These first period timing assumptions follow from the fact that I am ultimately interested in modeling the interaction between households and the government using a global games framework with binary actions for households. Obtaining binary actions as the optimal equilibrium outcome of a model with risk neutral preferences requires making assumptions on timing consistent with savings depending on fiscal policy only through the bond price.

In the second period the government decides whether or not to default on its liabilities, and the size of the haircut, h , as in Calvo (1988). I restrict h to lie in the interval $[0, \eta]$, with $\eta < 1$.⁴ Defaulting is not a free lunch: if the government defaults in the second period, the economy experiences an output loss lasting T periods. Assuming fixed output losses following a default episode is common in the international finance literature on sovereign default (e.g. Eaton and Gersovitz (1981) and Arellano (2008)). It should be interpreted as a reduced form way of capturing the consequences of financial crises and currency crises that typically hit a defaulting country. The government must balance default costs against the distorting effects of taxation. Finally, households work, pay taxes and consume their net income plus savings. A recap of the events most significant for default is presented in Fig. 2-3.

After a default episode, the economy experiences an output loss of size θ , in the spirit of Arellano (2008). The default cost θ is not common knowledge. Agents and

⁴This is because I am interested in comparing my results to those of a model with common knowledge, and I want to be able to obtain an equilibrium with positive borrowing and default which would not arise if I allowed $h = 1$. One could obtain an interior solution for h by introducing additional default costs as a convex function of h , but that would no longer yield a threshold default rule for the government and the model would become intractable.

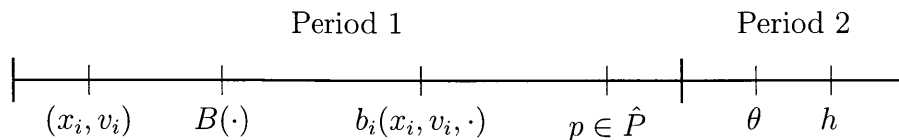


Figure 1-1: Timing of default-relevant events.

the government share a common Gaussian prior on θ with mean $\bar{\theta}_0$ and precision α_0 . The government does not observe the default cost or else there would be the additional complication of signaling, as studied by Angeletos, Hellwig, and Pavan (2006). In addition, households observe a Gaussian private signal x about θ , $x = \theta + \varepsilon_{x,i}$. $\varepsilon_{x,i}$ is iid normal across households, with mean zero and precision α_x . Households observe a second private Gaussian signal $v_i = \theta + s + u_i$. s is normal with mean zero and precision α_s . u_i is iid normal across households, with mean zero and precision α_u . Finally, s is independent of both u_i and ε_i .⁵ The shock s summarises correlated noise in private information, so it should be interpreted as capturing correlated movements in households' beliefs. Correlated noise in private signals s guarantees that the bond price does not restore common knowledge of the fundamental θ . Another way to achieve this result would have been to introduce noise traders à la Grossman and Stiglitz (1976). However, this approach has the disadvantage of not being micro-founded, which would make it more difficult to perform welfare comparisons since one would need to worry about how to treat the “irrational” agents.

The utility of household i is given by

$$U_i = \mathbb{E}_\theta \left[c_{i,1} - \frac{1}{\nu} n_{i,1}^\nu + \beta \left(c_{i,2} - \frac{1}{\nu} n_{i,2}^\nu \right) \middle| x_i, v_i, p \right] \quad (1.1)$$

Here, $c_{i,t}$ denotes the quantity of numeraire consumed by household i in period $t \in \{1, 2\}$; $n_{i,t}$ represents the number of hours worked by household i in period t ; β is the discount factor and $\frac{1}{1-\nu}$ equals the Frisch elasticity of labour supply.

Note that the expectation is taken with respect to the distribution of the fundamental θ , and that by conditioning on the private signals x_i and v_i , households take into account all available private information. Households also condition their decisions on the equilibrium bond price p , since they are allowed to submit complete demand schedules when financial markets open. Therefore, even though households do not observe the equilibrium price p before making consumption and saving decisions, they do make decisions contingent on all future realizations of p .

⁵I show later that there exists a linear sufficient statics for (x_i, v_i) . This continues to be true even with an arbitrary set of Gaussian signals and arbitrary correlations.

Each household has an identical initial endowment ω , which corresponds to initial wealth. Since the financial market closes before households receive income, household savings are bounded above by this wealth. Moreover, households cannot engage in short-selling, which puts a zero lower bound on savings. As a result, household savings is bounded above and below:

$$0 \leq b_i \leq \omega \quad (1.2)$$

Here, b_i denotes the units of consumption that household i lends to the government; b_i/p is the number of bonds purchased by household i . Finally, households are subject to budget constraints. In the first period, the budget constraint is:

$$c_{i,1} \leq w_1(1 - \tau_1)n_{i,1} + \omega - b_i \quad (1.3)$$

where w_1 denotes the hourly wage and τ_1 the labour tax rate. This equation states that a household uses labour income net of taxes $w_1(1 - \tau_1)h_{i,1}$ and wealth $\omega - b_i$ to finance consumption. In the second period, households have no additional wealth other than their position in bonds, so the budget constraint is:

$$c_{i,2} \leq w_2(1 - \tau_2)n_{i,2} - \theta \mathbf{1}\{h > 0\} + (1 - h)\frac{b_i}{p} \quad (1.4)$$

Here, h is the fraction of savings lost in a default episode, and τ_2 denotes the amount of taxes collected in period 2. θ represents the loss contingent on a default episode.

The objective of the household is to choose a bond demand schedule $b_i = b_i(x_i, v_i, p)$ to maximize expected utility (1.1) subject to its budget constraints (1.3) and (1.4), and its borrowing constraint (1.2).

The government is a benevolent dictator with limited commitment. The government's objective in the first period, $t = 1$, is given by the sum of household utilities:

$$\mathcal{W}_1 = \mathbb{E}_\theta \left\{ \int_{i \in [0,1]} \left[c_{i,1} - \frac{1}{\nu} n_{i,1}^\nu + \beta \left(c_{i,2} - \frac{1}{\nu} n_{i,2}^\nu \right) \right] di \mid p \right\} \quad (1.5)$$

The expectation is taken with respect to the distribution of the default cost θ and it is conditional on p . This captures the fact that the government realises that the bond price conveys information, and it takes into account in choosing the supply of bonds. In other words, by writing the expectation conditional on the bond price one addresses the question ‘‘Suppose the bond price turned out to be p , what would expected social welfare be given what the government has learnt?’’ for any possible value of the bond price. As a result, fiscal policy must be indexed by p : the

government chooses a borrowing schedule which is a function of the bond price, $B_1 = B_1(p)$.

The government faces budget constraints:

$$g_1 \leq \tau_1 w_1 N_1 + B \quad (1.6)$$

$$g_2 + (1 - h) \frac{B}{p} \leq \tau_2 w_2 N_2 \quad (1.7)$$

Here, B/p is the face value of the government's liabilities at $t = 2$. B is the amount of numeraire the government raises in period 1, defined as $B \equiv \int_{i \in [0,1]} b_i di$. N_t is aggregate labour supply, $N_t \equiv \int_{i \in [0,1]} N_{i,t} di$. Finally, g_t denotes government consumption at time t . The budget constraints state that the government relies on a combination of borrowing and taxes to finance government spending and liabilities. By defaulting at the haircut h , the government can reduce its bill in the second period. The government must also respect the resource constraints:

$$C_1 + g_1 \leq Y_1 + \omega \quad (1.8)$$

$$C_2 + g_2 + \theta \mathbf{1}\{h > 0\} \leq Y_2 \quad (1.9)$$

where C_t represents aggregate consumption, $C_t \equiv \int_{i \in [0,1]} c_{i,t} di$. The economy's resources in the first period are given by aggregate wealth, ω , plus income Y_1 . In the second period, they are simply Y_2 . In the first period, these resources are used for private and public consumption, $C_1 + g_1$. In the second period, the economy may suffer a size- θ output loss if the government defaults, so output is used to finance consumption and default costs. The government must take into account that the haircut h must lie in a closed and bounded interval:

$$0 \leq h \leq \eta \quad (1.10)$$

The bond market clearing condition implies that the government faces an additional "equilibrium" constraint. The aggregate demand for bonds is a function of the price p , the default cost θ and the correlated shock in households' beliefs, s . The supply of bonds, in turn, is a function of the bond price p . As a result, for any choice of the government's borrowing function $B(\cdot)$, bond market clearing defines an equilibrium price correspondence $\hat{P}[\theta, s; B(\cdot)]$. Since the price correspondence depends on the choice of the borrowing function, it works as an additional constraint on the government:

$$p \in \hat{P}[\theta, s; B(\cdot)] \quad (1.11)$$

The government must take into account how its choice of $B(\cdot)$ affects the relationship between the noise shock s , the fundamental θ and the equilibrium bond price p . In this sense, the government acts as a monopolist supplier of bonds who internalises the impact of supply decisions on prices.

In the first period, the government's problem amounts to choosing a borrowing function $B(p)$ and a current tax rate function $\tau_1(p)$ to maximise social welfare (1.5) subject to the budget constraints (1.6) and (1.7), the resource constraints (1.8) and (1.9), and the equilibrium constraint (1.11).

In the second period, the government observes θ prior to choosing how much to borrow and whether to default, so there is no uncertainty. Social welfare is given by:

$$\mathcal{W}_2 = \int_{i \in [0,1]} \left(c_{i,2} - \frac{1}{\nu} n_{i,2}^\nu \right) di \quad (1.12)$$

The government chooses borrowing B_2 , a tax rate τ_2 and a haircut h to maximise social welfare (1.12) subject to the budget constraint (1.7), the resource constraint (1.9), and the constraint on the haircut (1.10), for given θ .

There are three markets in this economy: a financial market which determines the price of government bonds p ; a labour market which determines the wage w_t and a market for the consumption good. The bond market clears when

$$B(p) = S(p, \theta, s) \quad (1.13)$$

Here, S denotes aggregate bond demand, that is, aggregate savings. Aggregating over individual savings $b_i(x_i, v_i, p)$, aggregate savings is defined as:

$$S(p, \theta, s) \equiv \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} b_i(x_i, v_i, p) \sqrt{\alpha_x} \phi[\sqrt{\alpha_x}(x_i - \theta)] \sqrt{\alpha_u} \phi[\sqrt{\alpha_u}(v_i - \theta - s)] dx_i dv_i \quad (1.14)$$

In words, market clearing happens when government borrowing, B , equals aggregate savings, S . Note that as anticipated in the description of the government's problem, the bond market clearing condition (1.15) implicitly defines the set of equilibrium prices, the correspondence \hat{P} :

$$\hat{P}[\theta, s; B(\cdot)] \equiv \{p : B(p) = S(p, \theta, s)\} \quad (1.15)$$

which is indexed by the fundamental θ and the aggregate shock s . As for the labour market, the production function is linear:

$$Y_t = A_t N_t$$

and A_t is labour productivity. The labour market is competitive, so equilibrium requires that the wage equals labour productivity:

$$w_t = A_t \tag{1.16}$$

Finally, the numeraire market clearing condition is given by the resource constraints (1.8) and (1.9), which state that the economy cannot consume more than it produces.

1.2 Equilibrium

In this economy, any borrowing function selected by the government induces an equilibrium, which is associated with some level of first-period social welfare. The government's problem then amounts to choosing a borrowing function and tax rate to select the equilibrium that maximises expected social welfare conditional on its budget, resource and equilibrium constraints. The equilibrium concept employed in this paper is a mixture of a perfect Bayesian and a Rational Expectations (RE) equilibrium.

Definition 1 (Equilibrium). For any arbitrary borrowing function $B(p)$ and common prior $f(\theta)$, a symmetric equilibrium is a pair of consumption functions for households $c_1(x, v, p)$ and $c_2(x, v, p, \theta)$, a savings function for households $b_1(x, v, p)$, a pair of labour supply function for households $n_1(x, v, p)$ and $n_2(x, v, p, \theta)$, a default decision $h(p, \theta)$, a second period tax rate function $\tau_2(p, \theta)$, a price correspondence $\hat{P}[\theta, s; B(\cdot)]$, wages w_1 and w_2 , posterior beliefs for households $f(\theta|x, v, p)$, and posterior beliefs for the government $f(\theta|p)$ such that:

- (1) $c_1(x, v, p)$, $c_2(x, v, p, \theta)$, $b_1(x, v, p)$, $n_1(x, v, p)$ and $n_2(x, v, p, \theta)$ maximise the expected utility of a household who's received private signals x and v for any value of p , (1.1), subject to the household's budget constraints (1.3) and (1.4) and to the household's borrowing constraint, (1.2);
- (2) $h(p, \theta)$ and $\tau_2(p, \theta)$ maximise social welfare as of $t = 2$, (1.12), subject to the government's budget constraint (1.7), to the government's resource constraint (1.9) and to the constraint that h is bounded above and below, (1.10);
- (3) the bond market clears, (1.15);
- (4) the labour market clears, (1.16);

(5) for any value of $p \in \hat{P}[\theta, s; B(\cdot)]$, $f(\theta|x, v, p)$ and $f(\theta|p)$ are formulated according to Bayes's Law.

The first condition represent optimality for households, while the second is optimality for the government. The third condition is bond market market clearing. Finally, the last condition requires that along the equilibrium path (that is, for any p that arises in equilibrium), posterior beliefs be computed by applying Bayes's Law. Away from the equilibrium path, beliefs are indeterminate.

The government takes into account that each choice of borrowing schedule induces an equilibrium. It chooses the borrowing function (and the corresponding current tax rate function) to select the equilibrium that maximises expected equilibrium social welfare (1.5) subject to the budget constraint (1.6), the resource constraint (1.8) and the equilibrium constraint (1.11).⁶

Definition 2 (Ramsey optimum.). Given a prior belief of the government $f(\theta)$, a Ramsey optimum is a borrowing schedule $B(p)$ and corresponding tax rate schedule $\tau_1(p)$ such that the induced symmetric equilibrium allocation functions $c_1(x, v, p)$, $c_2(x, v, p, \theta)$, $b_1(x, v, p)$, $n_1(x, v, p)$, and $n_2(x, v, p, \theta)$, equilibrium haircut function $h(p, \theta)$, equilibrium second period tax rate $\tau_2(p, \theta)$ and equilibrium price correspondence $\hat{P}[\theta, s; B(\cdot)]$ maximise expected equilibrium social welfare (1.5) computed according to the equilibrium posterior belief $f(\theta|p)$, subject to the budget constraint (1.6), the resource constraint (1.8) and the equilibrium constraint (1.11).

This may look like a standard Ramsey problem, but there is an important caveat. Since the government learns from equilibrium prices, it announces an entire borrowing schedule, as opposed to a borrowing level. Moreover, taking into account the information conveyed by prices is not the only advantage afforded by conditioning on the price. By doing so, the government can affect the coordination problem of households. If household i expects every other household to demand high interest rates, she reasons that default risk must be high, and so she demands a high rate in turn. There is a strategic complementarity between households. The government can affect this strategic complementarity by making borrowing conditional on the price. If, for instance, it were to choose a low level of borrowing when interest rates are high, it would lessen the positive correlation between interest rates and default risk, thereby causing households to demand lower interest rates for all values of the fundamentals.

In order to obtain closed form expressions for posterior beliefs, I restrict the class of equilibria to those such that the price correspondence $\hat{P}[\theta, s; B(\cdot)]$ depends

⁶The Ramsey problem is spelled out in the Appendix.

on the fundamental θ and the correlated noise s via a linear combination $z = \theta + \lambda s$, for some λ exogenous to the choice of $B(p)$. As a result, I can write $\hat{P}[\theta, s, B(\cdot)] = \hat{P}[z, B(\cdot)]$. The linear combination z works as a sufficient statistic for the bond price, so conditioning on z is equivalent to conditioning on p . Under the distributional assumption I have made on prior beliefs and on the private signals x_i and v_i , this equivalence will in turn enable me to characterise the posterior belief of households in closed form.

Moreover, I am only going to consider invertible selections $P[z, B(\cdot)]$ from the bond price correspondence $\hat{P}[z, B(\cdot)]$. This is because the solution algorithm I employ to solve the Ramsey problem requires that the price correspondence be single-valued and invertible (see Section 1.2.1).

1.2.1 Equilibrium characterisation

In this subsection, I show that the equilibrium is monotone and that the price conveys a Gaussian signal about the fundamental θ . In a monotone equilibrium, a household lends provided a linear combination of her private signals, $\hat{x} = a_x x + a_v v$ for some a_x and a_v , is (weakly) higher than some threshold $\hat{x}^*(p)$, so $b(p, x, v) > 0$ if and only if $\hat{x} \geq \hat{x}^*(p)$. The government defaults provided default costs are (weakly) lower than some threshold $\theta^*(p)$, so $h(p, \theta) > 0$ if and only if $\theta \leq \theta^*(p)$. An equilibrium is then characterised by fix objects: a borrowing function $B(p)$, a threshold signal function for households $\hat{x}^*(p)$, a default threshold function for the government $\theta^*(p)$, a price correspondence $\hat{P}(z)$, posterior beliefs for households and posterior beliefs for the government.

Because the government faces fixed costs of default, the equilibrium haircut h can only take the corner values $\{0, \eta\}$. In other words, if the government defaults, it does so at the highest possible haircut η . I show in the Appendix that the government follows a threshold default rule whereby it only defaults when the output loss associated with default is sufficiently low.

Claim 1 (Optimal default rule). *The government follows a threshold default rule such that*

$$h = \eta \text{ if } \theta \leq \theta^*(p) \quad \text{and} \quad h = 0 \text{ if } \theta > \theta^*(p)$$

Proof. See the Appendix. □

I also show that the default threshold $\theta^*(p)$ depends on the bond price p both directly and through government borrowing $B(p)$. In fact, with a slight abuse of notation, $\theta^*(p) = \theta^*(B(p)/p)$.

Writing the default threshold as a function of government liabilities B/p is useful to understand that a default episode may be triggered by high debt, high funding costs, or both. Suppose the market coordinates on a good equilibrium, so interest rates are low. The government may still default if debt is high enough. In this case, default risk amounts to solvency risk. Vice-versa if debt is low, there is still a possibility that the private sector coordinates on a bad equilibrium with high rates, thereby triggering default. Default risk is now entirely coordination risk. Generally, because borrowing depends on the bond price p which is in turn affected by the coordination problem of households embedded in the financial market, it is difficult to separate the solvency component from the coordination component of default risk.

The fact that the threshold is increasing in liabilities also helps to understand why conditioning on the bond price allows the government to affect the coordination problem of households. If household i expects everybody else to demand high interest rates, she reasons that default risk must be high - because the threshold θ^* is high - and so she demands high rates, too. The government can affect this strategic complementarity by making borrowing conditional on the price. If, for instance, it were to choose a low level of borrowing when interest rates are high, it would lessen the positive correlation between interest rates and default risk, thereby causing households to demand lower interest rates for all values of the fundamentals.

I now derive aggregate savings. Conjecture that there exists a sufficient statistic for the bond price

$$z = \theta + \lambda s \quad (1.17)$$

where λ is exogenous to the government's choice of borrowing. Conditional on θ , z is Gaussian with mean θ and precision $\alpha_z \equiv \lambda^{-2}\sigma_s^{-2}$. Under this conjecture, conditioning on z is equivalent to conditioning on p , so

$$\Pr\{\theta \leq \theta^*(p)|x, v, p\} = \Pr\{\theta \leq \theta^*(p)|x, v, z\}$$

As a result, the posterior default belief can be written as

$$\Pr\{\theta \leq \theta^*(p)|x, v, z\} = \Phi \left[\sqrt{\alpha_p^{HH}}(\theta^*(p) - \psi_0\bar{\theta}_0 - \psi_x x - \psi_v v - \psi_z z) \right] \quad (1.18)$$

where the posterior precision equals $\alpha_p^{HH} \equiv \alpha_0 + \alpha_x + \alpha_v + \alpha_z$. The weights are then given by $\psi_0 = \alpha_0/\alpha_p^{HH}$, $\psi_x = \alpha_x/\alpha_p^{HH}$ and so on. Now note that the posterior belief only depends on the private information (x, v) via the linear combination $\psi_x x + \psi_v v$. Define then $\hat{x}(x, v) \equiv x + (\psi_v/\psi_x)v$. Thus defined, \hat{x} is a linear sufficient statistic

for the private information vector (x, v) .

Conditional on beliefs given by (1.18), risk-neutral households lend if and only if they observe a high enough sufficient statistic \hat{x} about the state of the economy, so

$$b = 0 \quad \text{if } x < \hat{x}^*(p, z) \quad \text{and} \quad b = 1 \quad \text{if } x \geq \hat{x}^*(p, z) \quad (1.19)$$

Intuitively, the “better” private information, the greater the probability a household attaches to default costs being low. The threshold linear combination $\hat{x}^*(p, z)$ defines a “marginal” household that is indifferent between lending and not lending. As a result, $\hat{x}^*(p, z)$ is defined as the unique real number that satisfies the household indifference condition:

$$p = \beta[1 - \eta\Phi \left[\sqrt{\alpha_p^{HH}}(\theta^*(p) - \psi_0\bar{\theta}_0 - \psi_x x - \psi_v v - \psi_z z) \right]] \quad (1.20)$$

which states that a household is indifferent between saving and not saving when the expected return from holding the bond equals its price, p .⁷

Given the optimal savings function of households, I show in the Appendix that equilibrium aggregate savings is:

$$S(\theta, s, p, z) = \omega\Phi \left[\sqrt{\alpha_{\hat{x}}} \left(\frac{\psi_x + \psi_v}{\psi_x} \theta + \frac{\psi_v}{\psi_x} s - \hat{x}^*(p, z) \right) \right] \quad (1.21)$$

The right-hand side of equation (1.31) states that aggregate savings is computed as 1 minus the c.d.f. of \hat{x} conditional on θ and s , evaluated at $\hat{x}^*(p, z)$. Conditional on θ and s , \hat{x} is Gaussian with mean $\frac{\psi_x + \psi_v}{\psi_x} \theta + \frac{\psi_v}{\psi_x} s$ and precision $\alpha_{\hat{x}}$. Intuitively, if the government has a smaller commitment problem (higher θ) or if households perceive the government to have a smaller commitment problem (higher s), aggregate savings increases because the market expects default to be less likely. If the market becomes more pessimistic about the likelihood of a default episode so fewer households are willing to lend (higher $\hat{x}^*(p)$), aggregate savings decreases.

I next verify the conjecture that that observing the price p is equivalent to observing a public Gaussian signal about θ . To begin, note that aggregate savings (1.31) depends on the fundamental θ and the aggregate shock s only through the linear combination

$$\frac{\psi_x + \psi_v}{\psi_x} \left[\theta + \frac{\psi_v}{\psi_x + \psi_v} s \right] = \frac{\psi_x + \psi_v}{\psi_x} \zeta(\theta, s) \quad (1.22)$$

⁷The solution to the household optimisation problem is a savings correspondence such that for $\hat{x} = \hat{x}^*(p, z)$ the household is indifferent between saving any amount in $[0, \omega]$. Without loss of generality (because for a continuous random variable $\Pr\{X \leq x\} = \Pr\{X < x\}$), I assume that an indifferent household always chooses not to lend, so $b(p, \hat{x}^*(p, z), z) = 0$.

The bond market equilibrium condition, equation (1.15), can be thus written as:

$$\frac{\psi_x + \psi_v}{\psi_x} \zeta(\theta, s) = \frac{1}{\sqrt{\alpha_{\hat{x}}}} \Phi^{-1} \left[\frac{B(p)}{\omega} \right] + \hat{x}^*(p, z) \quad (1.23)$$

In this form, the bond market equilibrium condition states that for each possible value of p , common knowledge of the threshold $\hat{x}^*(p, z)$ and of the borrowing function $B(p)$ is equivalent to observing an endogenous public signal ζ about θ , which is normal with precision $\left(\frac{\psi_x + \psi_v}{\psi_v}\right)^2 \alpha_s$. Since conditioning on p and z is equivalent to conditioning on z , the equation implies that conditioning on z is equivalent to conditioning on ζ . Hence, letting

$$\lambda \equiv \frac{\psi_v}{\psi_x + \psi_v} \quad (1.24)$$

equation (1.23) verifies the conjecture that there exists a linear combination of the fundamental θ and the correlated shock s , $z = \theta + \lambda s$, that works as a sufficient statistic for the price. Conditional on θ , the signal z is Gaussian with precision $\alpha_z = \lambda^{-2} \alpha_s$.

Since conditioning on both p is equivalent to conditioning on z (because z is sufficient for p), for any p that arises along the equilibrium path, the government's posterior beliefs are normal:

$$\theta|z \sim \mathcal{N}(\psi \bar{\theta}_0 + (1 - \psi)z, \alpha_p^G) \quad (1.25)$$

with the mean equal to a linear combination of the prior mean $\bar{\theta}_0$ and the public signal z . Here, ψ represents the weight of the prior in the government's inference. It is given by $\psi \equiv \alpha_0 / \alpha_p^G$, with $\alpha_p^G \equiv \alpha_0 + \alpha_z$.

I next use the expression for households' posterior beliefs, (1.18), to write the indifference condition of households, equation (1.20), as:

$$\Phi[\tilde{p}(p)] = \sqrt{\alpha_p^{HH}} (\theta^*(p) - \psi_0 \bar{\theta}_0 - \psi_x \hat{x}^*(p, z) - \psi_z z) \quad (1.26)$$

where $\tilde{p}(p) \equiv \frac{1}{\eta} \left(1 - \frac{p}{\beta}\right)$. Substituting in for $\hat{x}^*(p, z)$ from the household indifference condition, equation (1.26), into the equilibrium condition, equation (1.23), and rearranging, one gets:

$$B(p) = \omega \Phi \left[\sqrt{\alpha_{\hat{x}}} \left(\frac{\psi_x + \psi_v + \psi_z}{\psi_x} z + \frac{1}{\psi_x} \frac{\Phi[\tilde{p}(p)]}{\sqrt{\alpha_p^{HH}}} - \frac{1}{\psi_x} \theta^*(p) + \frac{1}{\psi_x} \psi_0 \bar{\theta}_0 \right) \right] \quad (1.27)$$

In this form, the bond market clearing condition defines the equilibrium price correspondence for any realisation of the endogenous public signal z and any borrowing function $B(p)$, $\hat{P}[z; B(\cdot)]$.

Note that for any monotone selection from the correspondence $P[z, B(\cdot)]$, the private savings threshold $\hat{x}^*(p)$ can be found as $\hat{x}^*(p) \equiv \hat{x}^*[p, \hat{P}^{-1}(p)]$, since the function P is invertible.

The market clearing correspondence $\hat{P}[z; B(\cdot)]$ defined by equation (1.27) is non-empty as long as the borrowing schedule $B(p)$ is continuous in the interval $(\beta(1 - \eta), \beta)$. Whether the correspondence is multi- or single-valued depends on the interplay between government borrowing, $B(p)$, and aggregate savings. For starters, absent some restriction on the class of borrowing functions the government can choose from, the borrowing schedule $B(p)$ need not be monotonic (supply effect). Aggregate savings is also not necessarily monotonic in p . To see this, consider the right-hand side of equation (1.27), which represents equilibrium savings as a function of the endogenous public signal z and of the equilibrium bond price p . An increase in the equilibrium price p affects aggregate savings both via the default threshold θ^* (default effect) and by making the bond price more expensive, through the function \tilde{p} (cost effect). While the latter effect tends to decrease aggregate savings, the sign of the former is ambiguous, as it depends on the sign of the derivative of the default threshold θ^* with respect to p . This, in turn, depends on whether lower interest rates tend to increase or decrease government liabilities (recall that $\theta^*(p) = \theta^*[B(p)/p]$), which cannot be determined absent some restriction on the borrowing function $B(p)$. If, for instance, $B(p)$ were increasing in p and such that government liabilities were, in turn, increasing in p , the default effect would be positive. As a result, aggregate savings may be backward bending, provided the default effect was large enough to offset the cost effect.

These three potentially opposing effects - supply, default and cost - can be seen at work in the expression for the private information threshold, $\hat{x}^*(p)$. To characterise $\hat{x}^*(p)$, I use the indifference condition of households (1.26) to solve for z as a function of $\hat{x}^*(p)$. I then substitute for z into the equilibrium condition, (1.23). Re-arranging, I obtain:

$$\psi_x \hat{x}^*(p) = \underbrace{\theta^*(p)}_{\text{default effect}} - \psi_0 \bar{\theta}_0 - \underbrace{\frac{\Phi[\tilde{p}(p)]}{\sqrt{\alpha_p^{HH}}}}_{\text{cost effect}} - \frac{\psi_x \psi_z}{\psi_x + \psi_z} \frac{1}{\sqrt{\alpha_{\hat{x}}}} \underbrace{\Phi^{-1} \left[\frac{B(p)}{\omega} \right]}_{\text{supply effect}} \quad (1.28)$$

which shows that the identity of the marginal household $\hat{x}^*(p)$ is not necessarily monotonic in p .

To recap, the nature of the model implies that it is difficult to establish conditions for uniqueness without imposing restrictions on the space of borrowing functions the government may choose from. This is not the avenue I pursue though. Rather than solving the restricted problem of the government as a function of the equilibrium price, I solve a relaxed problem under the assumption that the government observes z and takes the price function as given. Under some conditions that are going to be satisfied in my simulations, the two problems are equivalent.

The equilibrium characterisation discussed so far implies that any optimal borrowing function $B(p)$ selected by the government induces a map from values of the public signal z to levels of borrowing, $\tilde{B} : \mathbb{R} \rightarrow (0, \omega)$, defined as $\tilde{B}(z) \equiv B[P(z)]$. Consider now a “relaxed” problem for the government such that (i) instead of observing the equilibrium price p , it observes the signal z and (ii) it takes a price function $\tilde{P}(z, B)$, consistent with market clearing, as given. This second problem is relaxed in the following sense. If the price correspondence associated to the original problem $P(z)$ were single-valued and invertible, the solution to the relaxed problem would be equivalent to the solution to the original problem $B(p)$, $B(p) \equiv \tilde{B}[P^{-1}(z)]$ and moreover, $P(z) \equiv \tilde{P}[z, \tilde{B}(z)]$.

The solution algorithm to retrieve the function $B(p)$ starts from this observation. Instead of solving the restricted government problem for $B(p)$, I solve the relaxed problem for $\tilde{B}(z)$ under the conjecture that $P(z)$ is invertible. First, I identify conditions under which I can solve uniquely for p as a function of z and B . This enables me to obtain a price function $\tilde{P}(z, B)$, such that

$$\begin{aligned} \tilde{P} : \mathbb{R} \times (0, \omega) &\rightarrow (\beta(1 - \eta), \beta) \\ (z, B) &\mapsto \tilde{P}(z, B) \end{aligned}$$

which is monotonic in z for all B in the set $(0, \omega)$. I then solve the relaxed problem. I obtain an optimal borrowing level as a function of z , the map $\tilde{B}(z)$, defined as:

$$\begin{aligned} \tilde{B} : \mathbb{R} &\rightarrow (0, \omega) \\ z &\mapsto \tilde{B}(z) \end{aligned}$$

Next, substituting $\tilde{B}(z)$ for B in $\tilde{P}(z, B)$, I obtain the equilibrium price as a map $P(z)$:

$$\begin{aligned} P : \mathbb{R} &\rightarrow (\beta(1 - \eta), \beta) \\ z &\mapsto \tilde{P}(z, \tilde{B}(z)) \end{aligned}$$

If $P(\cdot)$ were invertible, then the solution to the relaxed problem I found, $\tilde{B}(z)$, would also be a solution to the restricted problem, and $P(z)$ would also be the equilibrium price function associated with the restricted problem. The solution to the restricted government problem would then be a map, $B(p)$, defined as:

$$\begin{aligned} B : \mathcal{P} &\rightarrow (0, \omega) \\ p &\mapsto \tilde{B}(P^{-1}(p)) \end{aligned}$$

where \mathcal{P} denotes the range of P , $\mathcal{P} \equiv \{p \in (\beta(1 - \eta), \beta) : p = P(z)\}$ and $P^{-1}(\cdot)$ represents the inverse of $P(\cdot)$. The last step in the algorithm therefore requires verifying that the function $P(\cdot)$ is invertible.

By construction of the schedule $B(p)$, the level of borrowing that corresponds to any equilibrium price p is optimal given the corresponding value of z . In this sense, the optimal policy is time consistent. The government has not incentive to renege on its choice of $B(p)$ after the bond market clears and it observes the price signal z . The time consistency of policy arises because the continuation game associated with a particular value of z is independent of all other continuation games indexed by z . As an example of non-independent continuation games, consider a situation where the government's choice of policy affects the precision of information. Conditional on households' beliefs and z , the government may face a different trade-off ex-post than ex-ante.

I now turn to identifying a condition under which market-clearing yields a single-valued price correspondence $\tilde{P}(z, B)$ for any possible borrowing level. To start, rewrite the bond market equilibrium condition (1.27) evaluated at some value $B \in (0, \omega)$ rather than using the borrowing function $B(p)$:

$$\theta^*(p, B) - \psi_0 \bar{\theta}_0 - \frac{\Phi[\tilde{p}(p)]}{\sqrt{\alpha_p^{HH}}} + \frac{\psi_x}{\sqrt{\alpha_{\hat{x}}}} \Phi^{-1} \left[\frac{B}{\omega} \right] = (1 - \psi_0)z \quad (1.29)$$

Then consider the left-hand side of this equation as a function of p , and accordingly define a new function $G(p)$ as:

$$G(p) \equiv \theta^*(p, B) - \frac{\Phi[\tilde{p}(p)]}{\sqrt{\alpha_p^{HH}}}$$

The function $G(p)$ is such that $G : (\beta(1 - \eta), \beta) \rightarrow \mathbb{R}$, and it is continuous with $G(p) \rightarrow -\infty$ as $p \rightarrow \beta(1 - \eta)$ and $G(p) \rightarrow +\infty$ as $p \rightarrow \beta$. Therefore, a necessary and sufficient condition for the price correspondence to be single-valued is that the

derivative of G be positive for all $p \in (\beta(1-\eta), \beta)$ and all $B \in (0, \omega)$. This condition amounts to:

$$\inf_{\beta(1-\eta) < p < \beta, 0 < B < \omega} \left[-\frac{1}{\eta\beta} \frac{1}{\theta_p^*(p, B)} \frac{1}{\phi(\Phi[\tilde{p}(p)])} \right] > \sqrt{\alpha_p^{HH}}$$

Here, $\theta_p^*(p, B)$ denotes the partial derivative of the default threshold when θ^* is treated as a function of p and B . Since $\theta_p^*(p, B) < 0$, the left-hand side of the above inequality is positive.

Focusing on price uniqueness for any borrowing level rather than any borrowing function means we can do away with worrying about non-monotonicity of government borrowing $B(p)$, and focus on aggregate savings. As a result, we only have to deal with the default effect and the cost effect. With constant borrowing, the default effect is negative, since p affects government liability (and therefore θ^*) only through the interest rate. The uniqueness condition then guarantees that the negative default effect is dominated by the positive cost effect, and it amounts to a restriction on the overall precision of information α_p^{HH} . If $\sqrt{\alpha_p^{HH}}$ is sufficiently low, aggregate savings is downward sloping in prices. This is consistent with the results of Hellwig, Mukherji, and Tsyvinski (2006), who find that a necessary and sufficient condition for multiplicity is for households to be sufficiently well-informed.

1.2.2 Common knowledge benchmarks

I now characterise the equilibrium of the economy under common knowledge. I then use the common knowledge equilibrium to define what I mean by a solvent government and by an illiquid government in the context of this paper. These concepts underpin my decomposition of default risk into a solvency-risk component and a coordination-component.

Claim 2. *There exists values of the fundamental θ , $\underline{\theta}$ and $\bar{\theta}$, such that for $\theta \leq \underline{\theta}$, there exists a unique interior equilibrium with default and $p = \beta(1 - \eta)$; for $\theta > \underline{\theta}$, there exists a unique interior equilibrium without default and $p = \beta$; for $\theta \in (\underline{\theta}, \bar{\theta}]$, both equilibria may arise.*

Proof. See the Appendix. □

In the intermediate region of the fundamentals $(\underline{\theta}, \bar{\theta}]$, default risk amounts to coordination risk. Debt is sufficiently low and the commitment problem of the government sufficiently small that the fundamentals can sustain a good outcome, but the coordination problem of households may bring about a debt crisis. The

government fails to repay because agents coordinate on a bad equilibrium. For $\theta \leq \underline{\theta}$, the fundamentals are so bad that the government always defaults. In this region, there is no coordination risk and default risk amounts to solvency risk. Finally, for $\theta > \bar{\theta}$, the incentive to default is so small that a crisis never materialises. In this region, there is no risk.

In this paper, a solvent government is a government that repays its debts in full. The characterisation of the equilibrium with common knowledge shows that governments always pay back in full if $\theta > \bar{\theta}$. They also repay when $\theta > \underline{\theta}$, provided the market coordinates on a good equilibrium with low interest rates. As a result, I define a solvent government as a government that repays in full provided the fundamentals can sustain coordination on a good equilibrium with $p = \beta$.

Definition 3 (Solvency). A government is solvent if $\underline{\theta} < \theta$.

Some solvent governments are vulnerable to crises of confidence that result in high interest rates and default. Solvent governments that default because markets coordinate on a bad equilibrium with $p = \beta(1 - \eta)$ are defined to be illiquid.

Definition 4 (Illiquidity). A government is illiquid if $\underline{\theta} \leq \theta \leq \bar{\theta}$.

A common knowledge benchmark with exogenous coordination

In this subsection I consider a benchmark such that the government cannot affect coordination risk. Consider the following modifications to the baseline model presented in Section 2. Households have common knowledge about the output loss associated with default, θ . Unlike households, the government does not observe θ . Nonetheless, the government observes a noisy signal about the fundamental θ , z , described by (1.17). As a result, the government's posterior belief about θ is given by (1.25), as in the baseline model.

After having observed z , the government chooses borrowing to maximise expected social welfare taking into account second period optimality. The government conditions on the signal z as well as on the equilibrium price, p , so they choose a function $B(z, p)$. Thus the government has the same information as in the baseline model as well as equal ability to condition borrowing on the equilibrium bond price. In an economy with common knowledge amongst households, the equilibrium price is either $p = \beta$, without default, or $p = \beta(1 - \eta)$, with default. $B(z, p)$ is thus a map from $\mathbb{R} \times \{\beta(1 - \eta), \beta\}$ into $[0, \omega]$.

Given the level of borrowing chosen by the government for some z and $p = \beta(1 - \eta)$ households must correctly expect default, so it must be the case that $\theta \leq \theta^*[\beta(1 - \eta), B(z, \beta(1 - \eta))]$. An equilibrium without default, on the other hand, requires that

$\theta > \theta^*[\beta, B(z, \beta)]$. Note that if $\theta^*[\beta, B(z, \beta(1 - \eta))] > \theta^*[\beta(1 - \eta), B(z, \beta)]$, there would be a region of the fundamentals space that would not be consistent with any equilibrium. As a result, for any z the government must choose values of $B(z, \beta)$ and $B(z, \beta(1 - \eta))$ so that $\theta^*[\beta, B(z, \beta)] \leq \theta^*[\beta(1 - \eta), B(z, \beta(1 - \eta))]$.

Let now $\underline{\theta}(z) \equiv \theta^*[\beta, B(z, \beta)]$ and $\bar{\theta}(z) \equiv \theta^*[\beta, B(z, \beta(1 - \eta))]$. Since $\underline{\theta}(z) < \bar{\theta}(z)$, multiplicity ensues: for $\theta \in (\underline{\theta}(z), \bar{\theta}(z))$ both equilibria with and without default may arise, depending on households' expectations. In this region of the fundamentals, default risk amounts to coordination risk. Debt is sufficiently low and the commitment problem of the government sufficiently small that the fundamentals can sustain a good outcome, but the coordination problem of households may bring about a debt crisis. For $\theta \leq \underline{\theta}(z)$, the fundamentals are so bad that the government always defaults. In this region, there is no coordination risk and default risk amounts to solvency risk. Finally, for $\theta > \bar{\theta}(z)$, the incentive to default is so small that a crisis never materialises. In this region, there is no risk.

Following Cole and Kehoe (2000), I assume that in the intermediate region $\theta \in (\underline{\theta}(z), \bar{\theta}(z))$, coordination happens according to the realisation of a sunspot ζ , a random variable uniformly distributed in $[0, 1]$. The sunspot ζ is realised after the government's announcement of B , before households formulate their demand for bonds. For $\zeta \leq \pi$, households coordinate on the bad equilibrium with default, and vice-versa. π is therefore both the critical value of the sunspot and the probability of coordinating on the bad equilibrium. It is exogenous to the government's choice of B .

Figure 1-2 shows optimal borrowing B and the current tax rate τ_1 as functions of the government's signal, z , for an economy where the critical value of the sunspot is given by $\pi = 0.42$.⁸ Provided the government believes default costs to be high enough, they borrow less and tax more in an equilibrium with default. When the government believes default costs to be low enough, on the other hand, its posterior default probability is sufficiently high at all possible values of debt that it becomes optimal to jack up borrowing so as to decrease current distortions. This happens because the costs of default do not depend on the amount borrowed, a common assumption in the literature about sovereign default (see, for example, Eaton and Gersovitz (1981) and Arellano (2008)).

As z increases, the government's posterior belief puts greater weight on higher values of the default cost θ . This decreases the level of borrowing conditional on $p = \beta(1 - \eta)$, because when the government estimates higher average default costs they seek to

⁸This numerical simulation is based on a variant of the model fully described in Section 1.3. The value of π , 0.42, is derived as the expected value with respect to the distribution of z of an endogenous "equivalent" of π defined for the baseline model (see Section 1.3).

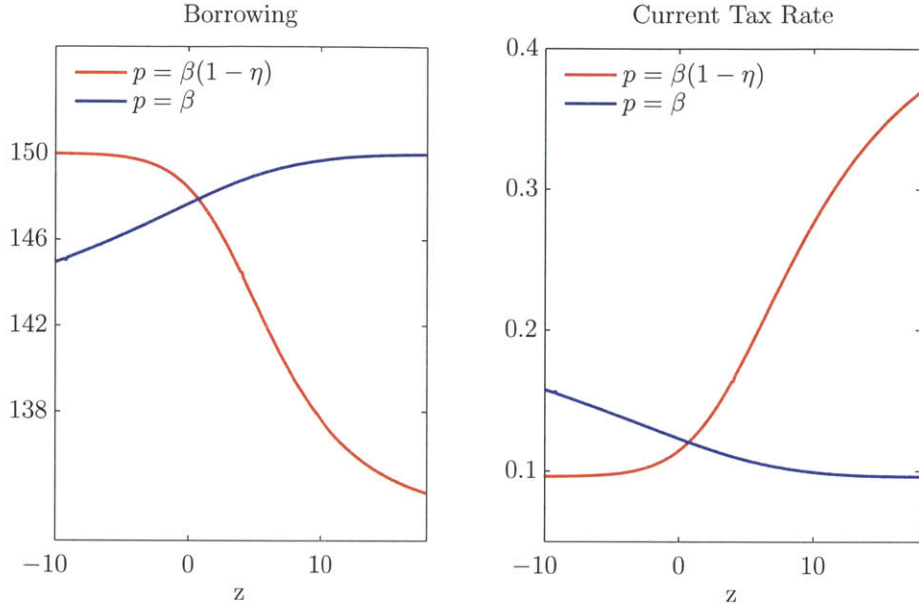


Figure 1-2: Optimal policy in the common knowledge benchmark with exogenous coordination. The figure shows equilibrium borrowing, B , as a function of the government’s signal z (left) and the equilibrium current tax rate, τ_1 , also as a function of z . The red lines refer to an equilibrium with default and $p = \beta(1 - \eta)$. The blue lines represent the alternative scenario without default and with $p = \beta$. The critical value of the sunspot, π , is assumed to be equal to 0.42.

decrease default risk by compressing the region where they are solvent but illiquid ($\bar{\theta}$ decreases). At the same time, it increases the level of borrowing conditional on $p = \beta$. This is because with high average default costs, even if the region where the government is insolvent increases ($\underline{\theta}$ increases), it absorbs a smaller probability mass provided the upper threshold is sufficiently far from the new mean (see Fig. 1-3). As a result, the government can afford higher borrowing and lower distortions at the same cost in terms of default risk.

I can now meaningfully introduce a decomposition for default risk into solvency-risk and coordination-risk. Conditional on z , default risk is given by:

$$\Pr\{h(p, \theta) = \eta | z\} = \Pr\{\theta \leq \underline{\theta}(z) | z\} + \pi[\Pr\{\theta \leq \bar{\theta}(z) | z\} - \Pr\{\theta \leq \underline{\theta}(z) | z\}]$$

The first component in the sum is the probability of being insolvent (solvency risk). The second is the probability of coordination on the bad equilibrium when the government finds itself in the intermediate region of fundamentals where it is solvent but illiquid (coordination risk). Coordination risk thus has two components: a “pure coordination” component, represented by π , and a “fundamentals” component, $\Pr\{\theta \leq \bar{\theta}(z) | z\} - \Pr\{\theta \leq \underline{\theta}(z) | z\}$. Fig. 1-4 illustrates the risk decomposition

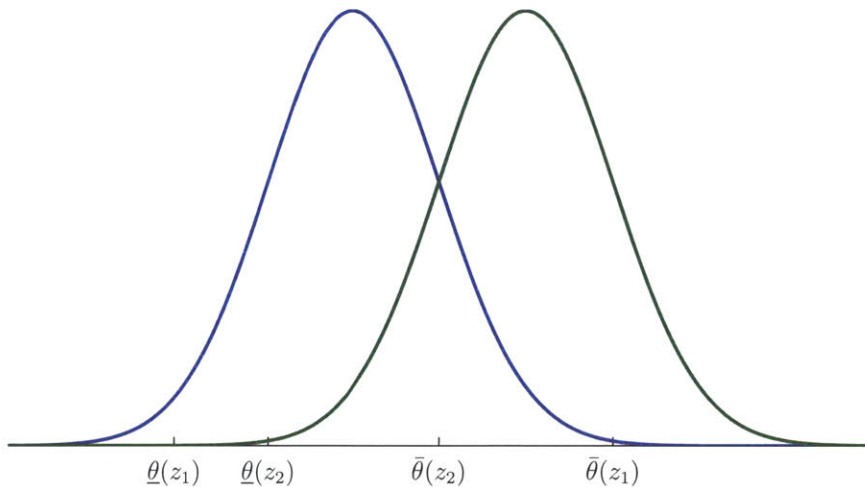


Figure 1-3: Common knowledge benchmark with exogenous coordination. Government’s posterior conditional on two different values of the signal z , $z_2 > z_1$. As z increases, the government estimates higher average default costs, $\psi\bar{\theta}_0 + (1 - \psi)z_2 > \psi\bar{\theta}_0 + (1 - \psi)z_1$. As a result, it becomes optimal to shrink the region of fundamentals where coordination is an issue, so $\underline{\theta}$ increases and $\bar{\theta}$ decreases. The increase in $\underline{\theta}$ does not come at the price of higher solvency risk as long as $\underline{\theta}(z_2)$ is sufficiently below the new mean, $\psi\bar{\theta}_0 + (1 - \psi)z_2$.

for an equilibrium with $\pi = 0.42$, along with the expected bond price. The figure shows that with common knowledge amongst households, coordination risk is a significant component of default risk.

The key property of this benchmark model is that the probability of coordinating on a good equilibrium, π , cannot be affected by the government. As a result, the government’s choice of borrowing, B , only reflects the government’s incentive to manipulate solvency risk. The government cannot affect the amount of coordination risk, although they can and do affect the region of fundamentals over which this risk is relevant. This does not seem to be a realistic assumption: surely a government should want to affect both types of risk to obtain maximum traction. It is therefore plausible that π should really be a function of B , $\pi = \pi(B)$. Unfortunately, the model with common knowledge amongst households does not impose any restraints on the shape of this function, which could thus be any arbitrary function of B mapping in $[0, 1]$. This problem can be overcome by using dispersed information, as the model generates an endogenous probability of default which depends on the government’s choice of borrowing function B .

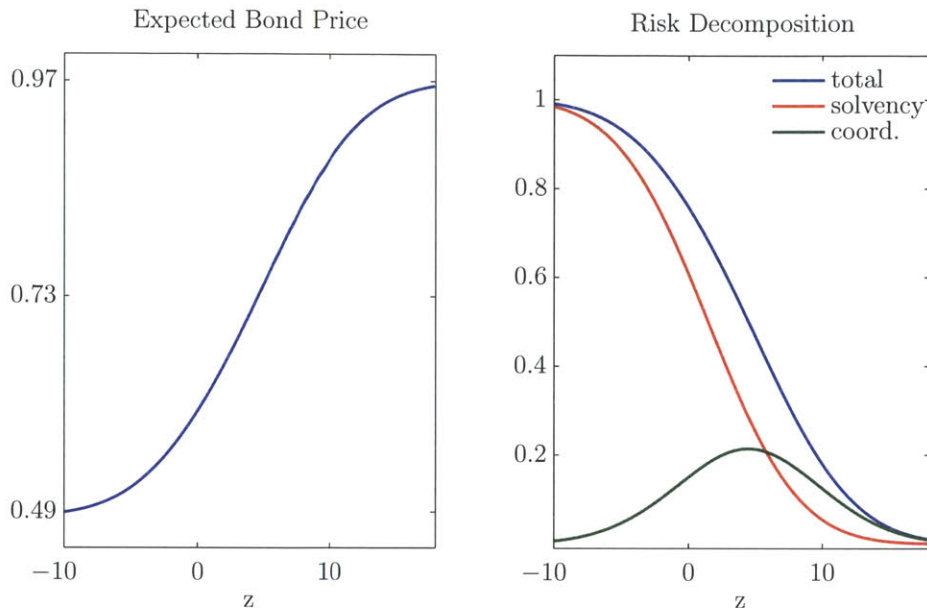


Figure 1-4: Common knowledge benchmark with exogenous coordination. The figure shows the expected bond price $\mathbb{E}_z P(z)$ (left) and the risk decomposition for an economy where the critical sunspot value, π , is equal to 0.42.

1.3 Baseline model: simulation results

For my simulations, I consider a modified version of the baseline model. In order to obtain reasonable values for government borrowing and the tax rate, I allow the government to borrow in the second period. I derive an expression for the government's continuation utility, V , as the continuation utility that would arise in an infinite horizon with commitment, $\bar{V}(B_2)$, adjusted for default costs, $v(h, \theta)$, so $V(B_2, h, \theta) \equiv \bar{V}(B_2) + v(h, \theta)$. Expressions for both $\bar{V}(B_2)$ and $v(h, \theta)$ are derived in the Appendix, where I also show that $\bar{V}(B_2)$ is decreasing in B_2 . The government must thus balance the benefit of borrowing in $t = 2$ against lower continuation utility V .

I make a second change to the baseline model in that I assume that government spending and productivity are constant, so $g_t \equiv g$ and $A_t \equiv A$. The government's incentive to borrow is now given by the presence of an initial stock of debt, $B_0 > 0$, priced at β . Theoretically, assuming (i) positive initial debt $B_0 > 0$ or (ii) $g_1 > g_2$ or (iii) $A_1 < A_2$ are all equivalent ways to get the government to borrow in period $t = 1$. Quantitatively, however, only the assumption of positive initial debt can generate borrowing levels consistent with what is empirically observed.

A key feature of the model proposed in Section 1.1 is that under dispersed information, coordination risk becomes endogenous to the government's payoff structure,

because it is affected by the government's choice of borrowing B (and the current tax rate τ_1). To see how the government's choice of fiscal policy feeds into coordination risk, recall the risk decomposition introduced in Section 1.2.2. In the common knowledge benchmark, π denotes the exogenous probability of coordination on the bad equilibrium, which happens when the realisation of the sunspot ζ is sufficiently low, $\zeta \leq \pi$. One can obtain a dispersed information analogue of π , $\pi(z, B)$, as the residual risk after subtracting solvency risk and conditioning on being in the solvent-but-illiquid region:

$$\pi(z, B) \equiv \max \left\{ 0, \min \left\{ \frac{\Pr\{\theta \leq \theta^*(z, B)|z\} - \Pr\{\theta \leq \underline{\theta}(B)|z\}}{\Pr\{\theta \leq \bar{\theta}(B)|z\} - \Pr\{\theta \leq \underline{\theta}(B)|z\}}, 1 \right\} \right\} \quad (1.30)$$

With dispersed information, then, the pure coordination component of coordination risk, π , becomes an endogenous variable to the planner's choice of B .

To illustrate the sensitivity of the equilibrium coordination risk, $\pi(z) \equiv \pi[z, B(z)]$, to the government's choice of policy, I first study a version of the model where debt is exogenous. I consider two perfectly inelastic borrowing schedules, such that $B(p) \equiv \underline{B}$ or $B(p) \equiv \bar{B}$, with $\underline{B} < \bar{B}$. I also consider an elastic borrowing schedule where debt is allowed to vary with p . By conditioning borrowing on p , the planner can distribute risk across values of the equilibrium interest rate, much as a standard Ramsey planner would distribute risk across different values of the fundamental θ by choosing state-contingent borrowing.

The three borrowing schedules are displayed in the left panel of Fig. 1-5, while the right panel shows coordination risk. By choosing an upward-sloping borrowing schedule, the planner is able to reduce coordination risk for high values of the interest rate (i.e. low z) and increase it for low values of the interest rate (i.e. high z). The intuition for this result is that by choosing an upward-sloping borrowing schedule, the planner obtains a flatter price schedule than he/she would by choosing an inelastic borrowing function. This contributes to shifting coordination risk across values of the interest rate by decreasing the threshold for low values of z and increasing it for high values of z .

Next, I allow the government to optimally choose borrowing as a function of p . I solve the restricted government problem as explained in Section 1.2.1. The bond price is monotonic in z : the more pessimistic the market (i.e. the lower z), the higher borrowing costs (see Fig. 1-6, right panel). This monotonicity verifies the conjecture underpinning the implementation algorithm described in Section ??, and the solution to the restricted government problem is shown in the left panel of

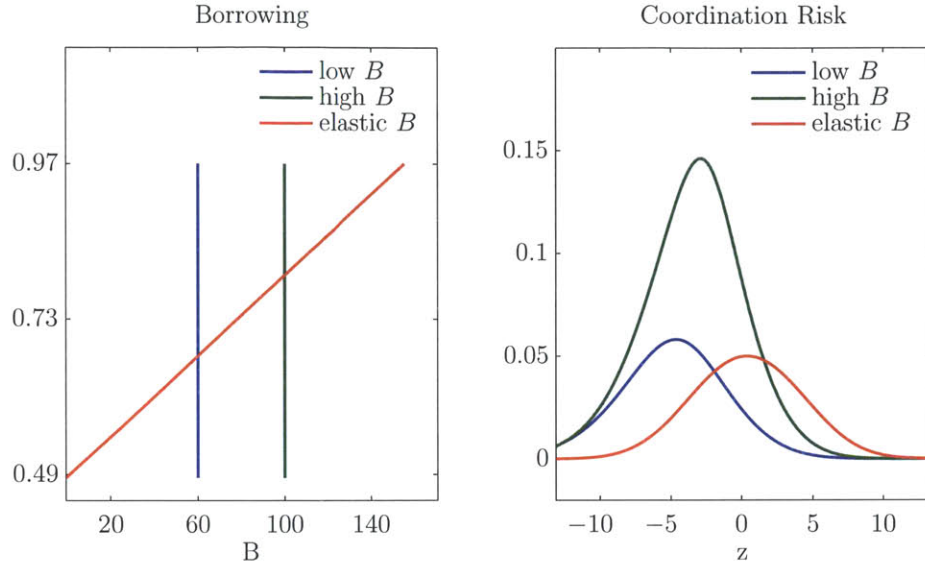


Figure 1-5: Model with exogenous borrowing. Equilibrium borrowing B as a function of the equilibrium price p (left) and equilibrium coordination risk (right) for different exogenous borrowing schedules. The blue line arises when a constant borrowing schedule is selected, \underline{B} . The green line is also associated with an inelastic borrowing schedule, but the level of borrowing is now given by \bar{B} . Finally, the red lines are associated with an elastic borrowing function linear in z , $B(p) = a + bp$ with $a = -155$ and $b = 319.6$.

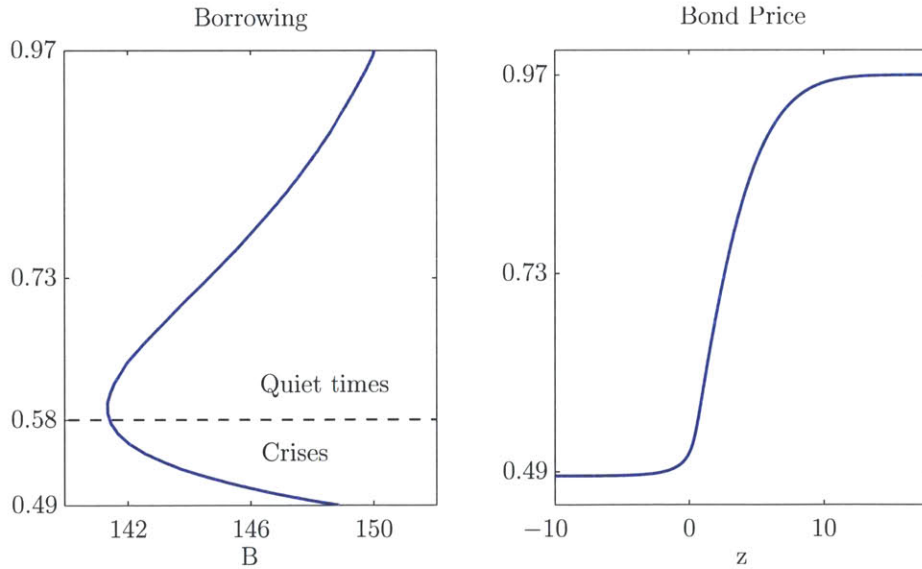


Figure 1-6: Baseline model. Equilibrium borrowing B as a function of the equilibrium price p (left) and equilibrium bond price as a function of the endogenous public signal z (right). Backward-bending optimal borrowing splits the space of interest rates into quiet times and crises.

Fig. 1-6.⁹ Government borrowing is not monotonic in interest rates. For low enough

⁹See Fig. 1-11 in the Appendix for a plot of the entire equilibrium and Fig. 1-12, also in the Appendix,

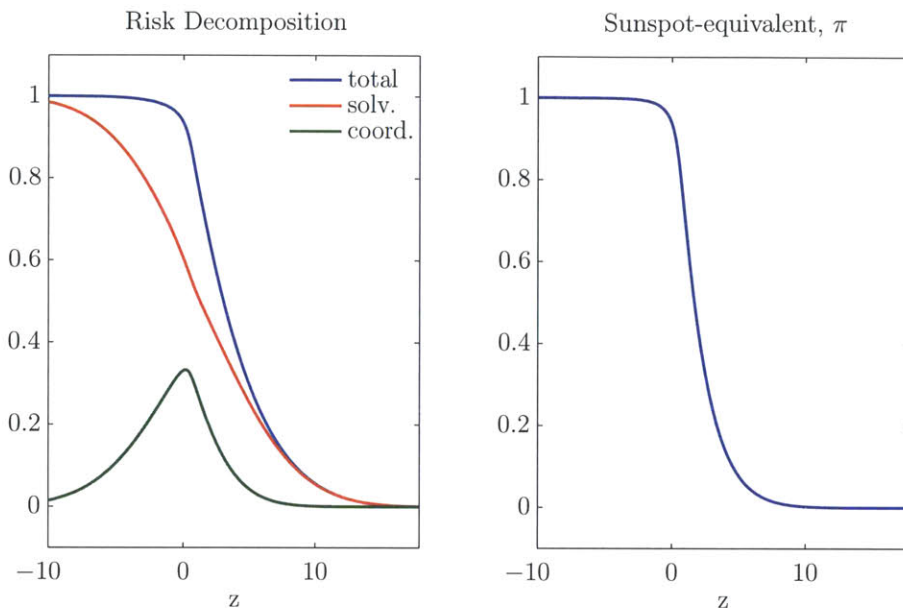


Figure 1-7: Baseline model risk decomposition. The left panel shows total risk (blue), solvency risk (green) and coordination risk (red). The right panel shows the function $\pi(z)$.

rates, a deterioration in market confidence resulting in higher funding costs (i.e. a fall in z) is associated with lower debt. Vice-versa, for sufficiently high interest rates, increased market pessimism is associated with higher borrowing. Therefore, there exists a critical value of the interest rate that splits the space of ex-post outcomes into two regions. There is a “quiet times” region where the market works as a disciplining device for the government because debt decreases with interest rates. However, there is also a “crisis” region where this disciplining mechanism breaks down and higher funding costs drive debt up.

The risk decomposition for the baseline model is presented in the left panel of Fig. 1-7. Intuitively, default risk is monotonic in the signal z , so the higher interest rates, the higher the risk of default. The figure also illustrates that coordination risk is a significant component of default risk, even when the government has the ability to optimally choose the distribution of risk across values of the interest rate. Finally, note that as the fundamentals improve (higher θ) or households perceive them to improve (higher s), the endogenous probability of coordinating on the bad equilibrium decreases. The function $\pi(z)$ is weakly decreasing in z (see Fig. 1-7, right panel).

To understand how the ability to optimally set coordination risk affects the shape of the optimal policy, I consider a variant of the model where the planner cannot

for the corresponding risk-decomposition.

affect coordination risk as reflected in the bond price. The government takes as given a price function of z and B derived from the indifference condition of households when the posterior belief about default is split into its components:

$$\tilde{P}(z, B) = \beta - \beta\eta \Pr\{\theta \leq \underline{\theta}(B)|z, \hat{x}^*(z, B)\} - \beta\eta\pi^B \Pr\{\underline{\theta}(B) < \theta \leq \bar{\theta}(B)|z, \hat{x}^*(z, B)\}$$

The government's choice of B affects both solvency risk and the risk of being solvent and illiquid but it does not affect the coordination probability conditional on being in the region of fundamentals where coordination is an issue, π^B . I consider both a situation where π^B is constant across z and a case where it is allowed to vary over z . The constant π^B is taken as the expected value of the $\pi(z)$ derived from the baseline model, $\pi^B = \mathbb{E}_z[\pi^M(z)]$, so $\pi^B = 0.42$. The z -varying exogenous coordination probability, $\pi^B(z)$, on the other hand, is taken as the one derived from the model as per the right panel of Fig. 1-7, so $\pi^B(z) = \pi^M(z)$.

Comparing the baseline model to this variant shows that the backward-bending nature of optimal borrowing cannot be ascribed to the ability to affect coordination risk. This feature of the optimal policy likely arises because of the assumption of the fixed default costs. As the interest rate increases and the planner estimates progressively lower default costs, at some point it becomes optimal to sacrifice higher default risk for lower tax distortions.¹⁰ Nonetheless, a planner who can affect coordination risk as reflected in prices chooses a more elastic cost-contingent schedule, and also one that features lower levels of borrowing.

1.4 Contingent fiscal targets

As I discussed in the Introduction, many economists read the European debt crisis that started in 2008 as a textbook example of multiple equilibria in action. Once a country gets into a bad equilibrium, a key question is whether it can do anything to get itself out of it. The traditional argument first proposed by Calvo (1988) is that countries should cap the rate at which they are willing to borrow, so as to rule out bad equilibria. If the market is unwilling to lend at the first best rate, a lender of last resort (LLR) should step in and provide liquidity at a suitable cost consistent with solvency. The recent experiences of Spain and Italy, however, suggest that countries are reluctant to appeal to an LLR, perhaps because such loans are perceived to be strategic substitutes to private sector lending, because they may come with “strings attached” in the form of costly adjustment policies, or for political economy reasons.

¹⁰Should have a variant of the model that shows this?

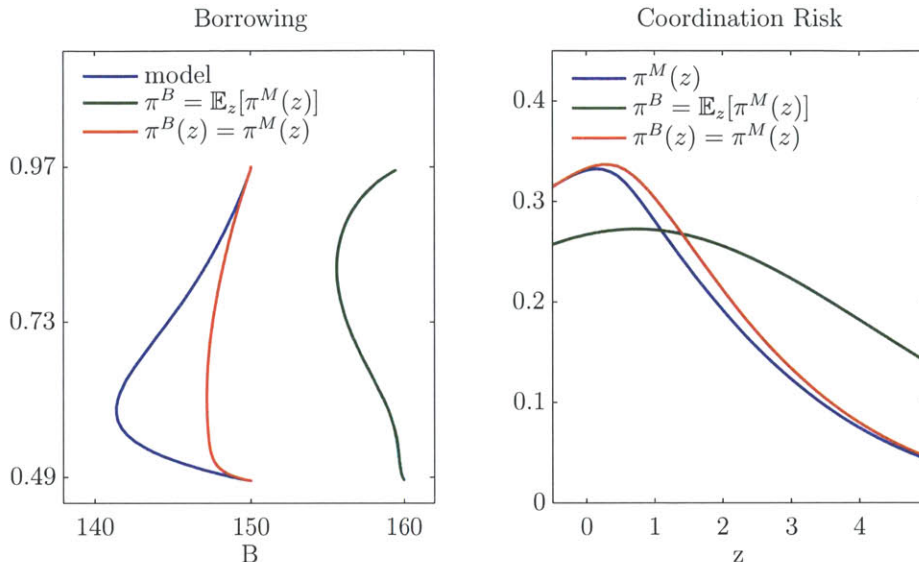


Figure 1-8: Baseline comparison with the exogenous coordination benchmark. Equilibrium borrowing B as a function of the equilibrium price p (left) and equilibrium coordination risk (right) for different exogenous borrowing schedules. The blue lines correspond to the baseline model. The green lines refer to the benchmark with exogenous coordination and constant π^B , $\pi^B \equiv \mathbb{E}_z[\pi^M(z)]$. The red lines refer to the benchmark with exogenous coordination and varying π^B , $\pi^B(z) \equiv \pi^M(z)$.

The model presented in this paper suggests a second way to improve on a bad equilibrium that is entirely self-reliant. Sovereigns faced with market panics may be able to transition to better equilibria by announcing cost-contingent borrowing targets rather than target borrowing levels. The right panel of Fig. 1-9 compares the funding costs of a government that commits to an optimal borrowing schedule to those of a government that commits to an optimal borrowing level (i.e. an inelastic borrowing schedule). A government that announces a contingent target can reduce both its borrowing costs and default risk relative to those faced by a government that announces a non-contingent target. These funding cost and risk reductions happen over a range of market sentiments which occur with a significant probability, approximately 30%.¹¹

The rationale for the cost and risk differential is that a government who commits to a contingent borrowing target is able to optimally affect the risk of coordination, an option that is not afforded to a government announcing a non-contingent target. As shown in Fig. 1-10, the first kind of government achieves a significant reduction

¹¹Recall that the unconditional distribution of z is normal with mean $\bar{\theta}_0$ and variance $\sigma_{z,U}^2 = \frac{1}{\alpha_0} + \frac{w_v^2}{(w_x + w_v)^2} \frac{1}{\alpha_s}$. Then $\Phi\left(\frac{4 - \bar{\theta}_0}{\sigma_{z,U}}\right) - \Phi\left(\frac{-1 - \bar{\theta}_0}{\sigma_{z,U}}\right) \approx 0.3$.

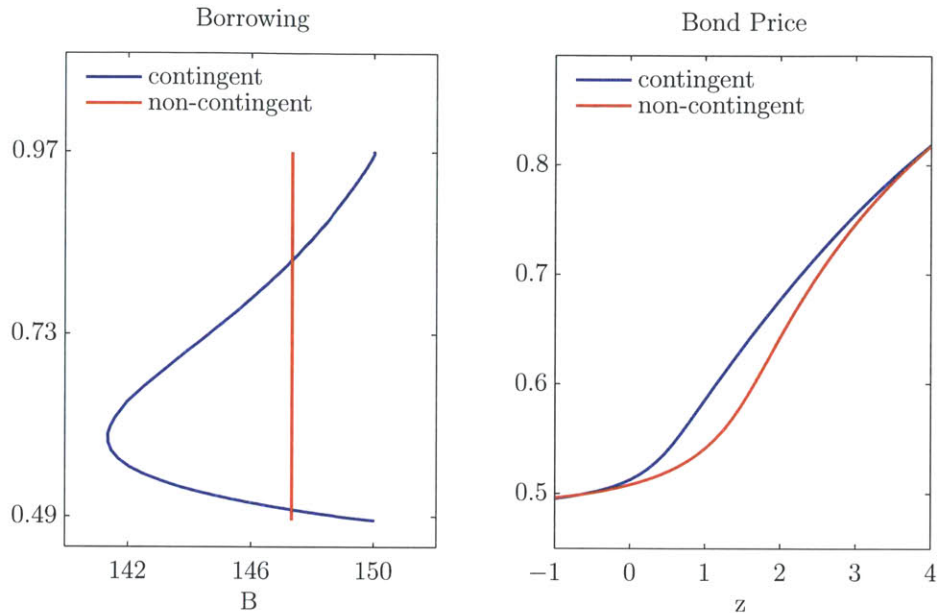


Figure 1-9: Equilibrium borrowing B as a function of the equilibrium price p (left) and equilibrium bond price as a function of the endogenous public signal z (right). The blue lines correspond to the model. The red lines represent the case of a government who cannot choose elastic borrowing schedules but must commit to a borrowing level instead. Choosing a contingent borrowing target reduces funding costs relatively to those that would pertain under a non-contingent borrowing target.

in coordination risk by optimally choosing its borrowing schedule so as to reduce the sunspot-equivalent component of coordination risk, $\pi(z)$.

1.5 Concluding remarks.

This paper emphasises the importance of fiscal policy - government borrowing and tax rates - in determining the risk of default during crises of confidence. Governments are not simply at the mercy of markets. On the contrary, by committing to cost-contingent borrowing targets, they can affect the coordination problem of households and thus reduce funding costs and default risk. This entirely self-reliant option ought to be especially welcome to troubled countries in a monetary union. As first noticed by De Grauwe (2011), the troubled economies of the Euro area periphery resemble emerging market economies in that, by foregoing the option of setting the inflation tax, they are effectively borrowing in foreign currency. Absent debt monetisation, these countries are one instrument short when it comes to default risk management, and not just any instrument. As underscored by the latest issue of the IMF World Economic Outlook (Oct., 2012), successful fiscal consolidations in developed economies have historically been accompanied by accommodative mone-

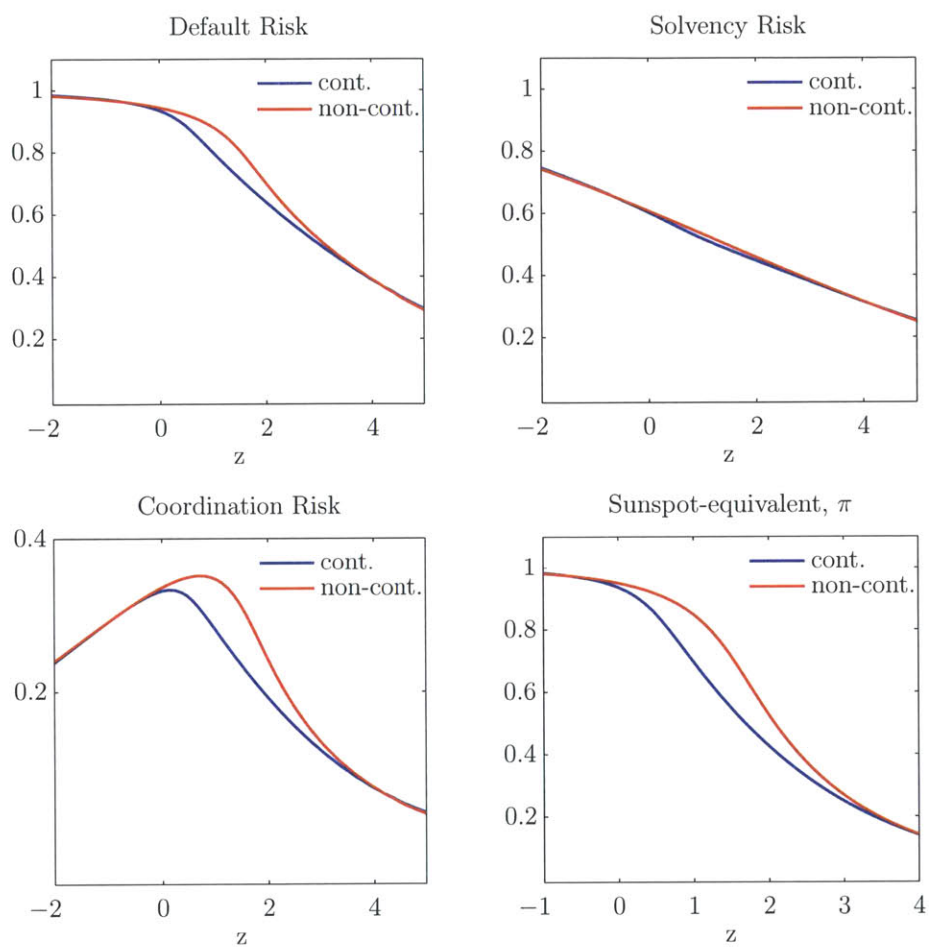


Figure 1-10: Risk decomposition as a function of the endogenous public signal z (right). The blue lines correspond to the model. The red lines represent the case of a government who cannot choose elastic borrowing schedules but must commit to a borrowing level instead. The risk differential from choosing contingent borrowing targets is driven by the differential in coordination risk.

tary policy. The report goes on to recommend a loose monetary policy environment for countries fighting against debt overhang, deploring the fact this possibility is foreclosed to countries in the Euro area (ch. 3). In such dire a situation, contingent targets may be a useful way to allow sovereigns some relief from market pressures.

1.6 Appendices

1.6.1 Theoretical part

Household optimality. Solving the optimisation problem of households returns:

$$n_{i,2} = w_2^{\frac{1}{\nu-1}} (1 - \tau_2)^{\frac{1}{\nu-1}}$$

so from households' budget constraint, second period consumption is given by:

$$c_{i,2} = w_2^{\frac{\nu}{\nu-1}} (1 - \tau_2)^{\frac{\nu}{\nu-1}} + (1 - h) \frac{b_i}{p}$$

Integrating over households, one obtains aggregate labour supply as a function of the second period tax rate τ_2 :

$$N_2 = w_2^{\frac{1}{\nu-1}} (1 - \tau_2)^{\frac{1}{\nu-1}}$$

and aggregate consumption as a function of borrowing B , the equilibrium price p and the second period tax rate τ_2 :

$$C_2 = w_2^{\frac{\nu}{\nu-1}} (1 - \tau_2)^{\frac{\nu}{\nu-1}} + (1 - h) \frac{B}{p}$$

As for the first period, the optimality conditions are given by:

$$\begin{aligned} \{n_{i,1}\} : & \quad n_{i,1} = w_1^{\frac{1}{\nu-1}} (1 - \tau_1)^{\frac{1}{\nu-1}} \\ \{c_{i,1}\} : & \quad 1 = \lambda_1 \\ \{c_{i,2}(\theta)\} : & \quad \beta f(\theta|x, v, p) = \lambda_2(\theta) \\ \{b_i\} : & \quad \lambda_1 + \mu^\omega - \mu^0 = \int_{\theta} \lambda_2(\theta) \frac{1 - h(p, \theta)}{p} d\theta \end{aligned}$$

where $\lambda_1 \geq 0$ is the multiplier of the first period budget constraint; $\lambda_2(\theta) \geq 0$ is the multiplier of the second period budget constraint when the state is θ ; $\mu^\omega \geq 0$ is the multiplier on the wealth constraint; $\mu^0 \geq 0$ the multiplier on the no-short-selling constraint and $f(\theta|x, v, p)$ denotes the household's posterior about the state θ conditional on p , x and v . Combining the optimality conditions returns a savings

correspondence for households such that:

$$b_i = \begin{cases} 0 & \text{if } p > \beta \int_{\theta} (1 - h(p, \theta)) f(\theta|x, v, p) d\theta \\ \in [0, \omega] & \text{if } p = \beta \int_{\theta} (1 - h(p, \theta)) f(\theta|x, v, p) d\theta \\ \omega & \text{if } p < \beta \int_{\theta} (1 - h(p, \theta)) f(\theta|x, v, p) d\theta \end{cases}$$

Consumption $c_{i,1}$ can then be derived from the household's first period budget constraint as

$$c_{i,1} = w_1^{\frac{\nu}{\nu-1}} (1 - \tau_1)^{\frac{\nu}{\nu-1}} - b_i$$

Aggregating across households, one gets an expression for aggregate consumption as a function of τ_1 and B :

$$C_1 = w_1^{\frac{\nu}{\nu-1}} (1 - \tau_1)^{\frac{\nu}{\nu-1}} - B$$

and aggregate labour supply:

$$N_1 = w_1^{\frac{1}{\nu-1}} (1 - \tau_1)^{\frac{1}{\nu-1}}$$

as a function of the first period tax rate τ_1 . □

Proof of Claim 1. The government's problem in the second period is given by:

$$\begin{aligned} \max_{C_2, N_2, \tau_2, h} \quad & C_2 - \frac{1}{\nu} N_2^{\nu} \\ \text{subject to} \quad & g_2 + (1 - h) \frac{B}{p} \leq w_2 \tau_2 N_2 \\ & C_2 + g_2 + \theta \{h > 0\} \leq Y_2 \\ & N_2 = w_2^{\frac{1}{\nu-1}} (1 - \tau_2)^{\frac{1}{\nu-1}} \\ & Y_2 = A_2 N_2 \\ & w_2 = A_2 \end{aligned}$$

where C_2 denotes aggregate consumption and N_2 aggregate labour supply. Using the results from the households' optimisation problem to write the Ramsey problem in terms of variables under the control of the government, one obtains:

$$\begin{aligned} \max_{\tau_2, h} \quad & A_2^{\frac{\nu}{\nu-1}} (1 - \tau_2)^{\frac{1}{\nu-1}} - g_2 - \frac{1}{\nu} A_2^{\frac{\nu}{\nu-1}} (1 - \tau_2)^{\frac{\nu}{\nu-1}} - \theta \mathbf{1}\{h > 0\} \\ \text{subject to} \quad & g_2 + (1 - h) \frac{B}{p} \leq A_2^{\frac{\nu}{\nu-1}} \tau_2 (1 - \tau_2)^{\frac{1}{\nu-1}} \end{aligned}$$

The F.O.C. for the tax rate is given by:

$$\lambda = \frac{\tau_2}{\nu} \left(\frac{\nu-1}{\nu} - \tau_2 \right)^{-1}$$

so $\lambda > 0$ and $\tau_2 < \frac{\nu-1}{\nu}$. The optimal haircut is either 0 or η . When the haircut is such that $h = 0$, the optimal tax rate is a solution to

$$g_2 + \frac{B}{p} = A_2^{\frac{\nu}{\nu-1}} \tau_2^{ND} (1 - \tau_2^{ND})^{\frac{1}{\nu-1}}$$

while when the haircut is such that $h = \eta$, the tax rate satisfies:

$$g_2 + (1 - \eta) \frac{B}{p} = A_2^{\frac{\nu}{\nu-1}} \tau_2^D (1 - \tau_2^D)^{\frac{1}{\nu-1}}$$

Given that $\tau_2 < \frac{\nu-1}{\nu}$, the right-hand side of these equations is increasing in τ_2 , so we have that $\tau_2^D < \tau_2^{ND}$. Note that taxes are increasing in liabilities:

$$\begin{aligned} \frac{d\tau_2}{d\frac{B}{p}} &= (1-h) A_2^{-\frac{\nu}{\nu-1}} (1-\tau_2)^{-\frac{1}{\nu-1}} \left(1 - \frac{\tau_2}{1-\tau_2} \frac{1}{\nu-1} \right)^{-1} > 0 \\ &= (1-h) A_2^{-\frac{\nu}{\nu-1}} (1-\tau_2)^{-\frac{1}{\nu-1}} \frac{(\nu-1)(1-\tau_2)}{\frac{\nu-1}{\nu} - \tau_2} \frac{1}{\nu} > 0 \end{aligned}$$

because $\tau_2 < \frac{\nu-1}{\nu}$. For a given haircut h , second period welfare is then given by:

$$A_2^{\frac{\nu}{\nu-1}} (1-\tau_2)^{\frac{1}{\nu-1}} \left[1 - \frac{1-\tau_2}{\nu} \right] - g_2 - \theta \mathbf{1}\{h > 0\}$$

Since the costs of default do not depend on the haircut, if the government defaults it does so at the highest possible rate, $h = \eta$. The government defaults if:

$$\theta < A_2^{\frac{\nu}{\nu-1}} \left[(1-\tau_2^D)^{\frac{1}{\nu-1}} \left(1 - \frac{1-\tau_2^D}{\nu} \right) - (1-\tau_2^{ND})^{\frac{1}{\nu-1}} \left(1 - \frac{1-\tau_2^{ND}}{\nu} \right) \right] \equiv \theta^*$$

For $\theta > \theta^*$, the government does not default, and for $\theta = \theta^*$ the government is indifferent. Without loss of generality (because for a continuous random variable $\Pr\{X \leq x\} = \Pr\{X < x\}$), I assume that an indifferent government defaults. Since the second period tax rate τ_2 is a function of government liabilities, B/p , the threshold is also a function of liabilities, $\theta^*(B/p)$. However, since equilibrium borrowing B is a function of the equilibrium price, we have that the threshold is a

function of the price really, $\theta^*(p)$. One can then write the optimal haircut as:

$$h = \eta \text{ if } \theta \leq \theta^*(p) \quad \text{and} \quad h = 0 \text{ if } \theta > \theta^*(p)$$

which states that the government follows a threshold default rule. \square

Proof that θ^ is decreasing in $\frac{B}{p}$.* To start, the derivative of welfare with respect to liabilities is given by:

$$\begin{aligned} \frac{\mathcal{W}_2}{d\frac{B}{p}} &= -A_2^{\frac{\nu}{\nu-1}} \left(\frac{1}{\nu-1} (1-\tau_2)^{\frac{1}{\nu-1}-1} - \frac{1}{\nu-1} (1-\tau_2)^{\frac{\nu}{\nu-1}-1} \right) \frac{d\tau^2}{d\frac{B}{p}} \\ &= -(1-\tau_2)^{\frac{1}{\nu-1}} \frac{A_2^{\frac{\nu}{\nu-1}}}{\nu-1} \left(\frac{\tau_2}{1-\tau_2} \right) \frac{d\tau^2}{d\frac{B}{p}} \\ &= -(1-\tau_2)^{\frac{1}{\nu-1}} \frac{A_2^{\frac{\nu}{\nu-1}}}{\nu-1} \left(\frac{\tau_2}{1-\tau_2} \right) (1-h) A_2^{-\frac{\nu}{\nu-1}} (1-\tau_2)^{-\frac{1}{\nu-1}} \left(1 - \frac{\tau_2}{1-\tau_2} \frac{1}{\nu-1} \right)^{-1} \\ &= -\frac{1}{\nu-1} \frac{\tau_2}{1-\tau_2} (1-h) \left(1 - \frac{\tau_2}{1-\tau_2} \frac{1}{\nu-1} \right)^{-1} \\ &= -\frac{\tau_2(1-h)}{\nu \left(\frac{\nu-1}{\nu} - \tau_2 \right)} \end{aligned}$$

Differentiating the threshold with respect to B/p then yields:

$$\begin{aligned} \frac{d\theta^*}{d\frac{B}{p}} &= -\frac{\tau_2^D(1-\eta)}{\nu \left(\frac{\nu-1}{\nu} - \tau_2^D \right)} + \frac{\tau_2^{ND}}{\nu \left(\frac{\nu-1}{\nu} - \tau_2^N \right)} \\ &= \frac{\tau_2^D \eta}{\nu \left(\frac{\nu-1}{\nu} - \tau_2^D \right)} + \frac{\tau_2^{ND}}{\nu \left(\frac{\nu-1}{\nu} - \tau_2^N \right)} - \frac{\tau_2^D}{\nu \left(\frac{\nu-1}{\nu} - \tau_2^D \right)} > 0 \end{aligned}$$

since (i) $\tau_2 < \frac{\nu-1}{\nu}$ and (ii) the function $\frac{x}{\frac{\nu-1}{\nu}-x}$ is increasing, and $\tau_2^{ND} > \tau_2^D$. \square

The Ramsey problem. The government's problem in the first period is given by

$$\begin{aligned}
& \max_{C_1, C_2, N_1, N_2, B, \tau_1, \tau_2, h} && C_1 - \frac{1}{\nu} N_1^\nu + \int_{\theta} \left[\beta \left(C_2 - \frac{1}{\nu} N_2^\nu \right) \right] f(\theta|p) d\theta \\
& && \text{subject to} \\
& && g_1 \leq w_1 \tau_1 N_1 + B \\
& && g_2 + (1-h) \frac{B}{p} \leq w_2 \tau_2 N_2 \\
& && C_1 + g_1 \leq Y_1 + \omega \\
& && C_2 + g_2 + \theta \{h > 0\} \leq Y_2 \\
& && N_1 = w_1^{\frac{1}{\nu-1}} (1 - \tau_1)^{\frac{1}{\nu-1}} \\
& && N_2 = w_2^{\frac{1}{\nu-1}} (1 - \tau_2)^{\frac{1}{\nu-1}} \\
& && Y_1 = A_1 N_1 \\
& && Y_2 = A_2 N_2 \\
& && w_1 = A_1 \quad \text{and} \quad w_2 = A_2 \\
& && p \in \hat{P}(\theta, s; B)
\end{aligned}$$

where $f(\theta|p)$ denotes the government's posterior about the state θ conditional on p , and it is given by equation (1.25) in the text. Taking into account equilibrium conditions, the Ramsey problem becomes:

$$\begin{aligned}
& \max_{B, \tau_1} && \left\{ A_1^{\frac{\nu}{\nu-1}} (1 - \tau_1)^{\frac{1}{\nu-1}} \left[1 - \frac{1 - \tau_1}{\nu} \right] - g_1 \right. \\
& && \left. + \beta \int_{\theta} \left[A_2^{\frac{\nu}{\nu-1}} (1 - \tau_2)^{\frac{1}{\nu-1}} \left[1 - \frac{1 - \tau_2}{\nu} \right] - g_2 - \theta \mathbf{1}\{h > 0\} \right] f(\theta|p) d\theta \right\} \\
& && \text{subject to} \\
& && p \in \hat{P}(\theta, s; B) \\
& && g_1 \leq A_1^{\frac{\nu}{\nu-1}} \tau_1 (1 - \tau_1)^{\frac{1}{\nu-1}} + B \\
& && A_2^{\frac{\nu}{\nu-1}} \tau_2 (1 - \tau_2)^{\frac{1}{\nu-1}} = g_2 + (1-h) \frac{B}{p} \\
& && h = \eta \text{ if } \theta \leq \theta^*(p) \quad \text{and} \quad h = 0 \text{ if } \theta > \theta^*(p)
\end{aligned}$$

where both B and τ_1 are functions of the equilibrium price p , $B = B(p)$ and $\tau_1 = \tau_1(p)$. \square

Proof of Claim 2 (equilibrium with common knowledge). In equilibrium, it must be

the case that $p = \beta(1 - h)$, so the government solves:

$$\max_{B, \tau_1} \left\{ A_1^{\frac{\nu}{\nu-1}} (1 - \tau_1)^{\frac{1}{\nu-1}} \left[1 - \frac{1 - \tau_1}{\nu} \right] - g_1 + \beta \left[A_2^{\frac{\nu}{\nu-1}} (1 - \tau_2)^{\frac{1}{\nu-1}} \left[1 - \frac{1 - \tau_2}{\nu} \right] - g_2 - \theta \right] \right\}$$

subject to

$$g_1 \leq A_1^{\frac{\nu}{\nu-1}} \tau_1 (1 - \tau_1)^{\frac{1}{\nu-1}} + B$$

$$A_2^{\frac{\nu}{\nu-1}} \tau_2 (1 - \tau_2)^{\frac{1}{\nu-1}} = g_2 + \frac{B}{\beta}$$

Government borrowing and the tax rate therefore satisfy the optimality conditions:

$$\{\tau_1\} : \lambda = \frac{\tau_1}{\nu} \left(\frac{\nu - 1}{\nu} - \tau_1 \right)^{-1}$$

$$\{B\} : \lambda = \beta \frac{A_2^{\frac{\nu}{\nu-1}}}{\nu - 1} \frac{\tau_2}{1 - \tau_2} (1 - \tau_2)^{\frac{1}{\nu-1}} \frac{d\tau_2}{dB}$$

where

$$\frac{d\tau_2}{dB} = \beta^{-1} A_2^{-\frac{\nu}{\nu-1}} (1 - \tau_2)^{-\frac{1}{\nu-1}} \left(1 - \frac{1}{\nu - 1} \frac{\tau_2}{1 - \tau_2} \right)^{-1}$$

Now suppose there exists an equilibrium with default. For this to be an equilibrium, it must be the case that $\theta \leq \theta^*[\beta(1 - \eta), B]$. Let $\bar{\theta} \equiv \theta^*[B/\beta(1 - \eta)]$. It is easy to show that the condition $\theta \leq \bar{\theta}$ is not only necessary but also sufficient for the existence of an equilibrium with default (assume that there exists an equilibrium with default and that $\theta > \bar{\theta}$ to obtain a contradiction). Vice-versa, suppose there exists an equilibrium without default. For this to be an equilibrium, it must be the case that $\theta > \theta^*[B, B]$. Let $\underline{\theta} \equiv \theta^*[B/\beta]$. By a similar argument as in the case of an equilibrium with default, the condition that $\theta > \underline{\theta}$ is not only necessary, but also sufficient, for an equilibrium without default to exist. Since borrowing is the same across the two equilibria, and the threshold θ^* is decreasing in p , it follows that $\underline{\theta} < \bar{\theta}$, which concludes the proof. \square

Ramsey problem with common knowledge amongst households. Let the superscript D denote policy when $p = \beta(1 - \eta)$ and ND policy when $p = \beta$. The Ramsey

problem is then given by:

$$\begin{aligned}
\max_{B^D, \tau_1^D, B^{ND}, \tau_1^{ND}} & \left[A_1^{\frac{\nu}{\nu-1}} (1 - \tau_1^D)^{\frac{1}{\nu-1}} \left(1 - \frac{1 - \tau_1^D}{\nu} \right) \right. \\
& \left. + \beta A_2^{\frac{\nu}{\nu-1}} (1 - \tau_2^D)^{\frac{1}{\nu-1}} \left(1 - \frac{1 - \tau_2^D}{\nu} \right) \right] \left[\int_{-\infty}^{\underline{\theta}(B^{ND})} f(\theta|z) d\theta + \pi \int_{\underline{\theta}(B^{ND})}^{\bar{\theta}(B^D)} f(\theta|z) d\theta \right] \\
& + \left[A_1^{\frac{\nu}{\nu-1}} (1 - \tau_1^{ND})^{\frac{1}{\nu-1}} \left(1 - \frac{1 - \tau_1^{ND}}{\nu} \right) \right. \\
& \left. + \beta A_2^{\frac{\nu}{\nu-1}} (1 - \tau_2^{ND})^{\frac{1}{\nu-1}} \left(1 - \frac{1 - \tau_2^{ND}}{\nu} \right) \right] \left[(1 - \pi) \int_{\underline{\theta}(B^{ND})}^{\bar{\theta}(B^D)} f(\theta|z) d\theta \right. \\
& \left. + \int_{\bar{\theta}(B^D)}^{+\infty} f(\theta|z) d\theta \right] \\
& - \int_{-\infty}^{\underline{\theta}(B^{ND})} \theta f(\theta|z) d\theta - \pi \int_{\underline{\theta}(B^{ND})}^{\bar{\theta}(B^D)} \theta f(\theta|z) d\theta - g_1 - \beta g_2
\end{aligned}$$

subject to

$$\begin{aligned}
g_1 & \leq A_1^{\frac{\nu}{\nu-1}} \tau_1^j (1 - \tau_1^j)^{\frac{1}{\nu-1}} + B^j \quad \text{for } j \in \{D, ND\} \\
A_2^{\frac{\nu}{\nu-1}} \tau_2^j (1 - \tau_2^j)^{\frac{1}{\nu-1}} & = g_2 + \frac{B^j}{\beta} \quad \text{for } j \in \{D, ND\}
\end{aligned}$$

□

Derivation of equation (1.31) in the text. To derive an expression for aggregate savings, observe that aggregate savings is simply 1 minus the c.d.f. of \hat{x} conditional on θ and s computed in $\hat{x}^*(p)$. The distribution of \hat{x} conditional on θ and s is given by:

$$\hat{x}|\theta, s \sim \mathcal{N} \left(\frac{\psi_x + \psi_v}{\psi_x} \theta + \frac{\psi_v}{\psi_x} s, \alpha_{\hat{x}} \right)$$

where $\alpha_{\hat{x}}$ equals

$$\alpha_{\hat{x}} \equiv \frac{\psi_x^2}{\psi_v^2} \sigma_s^{-2} = \frac{\psi_x^2}{\psi_v^2} \alpha_s$$

Since the conditional distribution of \hat{x} is normal and $1 - \Phi(x) = \Phi(-x)$, aggregate savings is equal to:

$$S(\theta, s, p, z) = \omega \Phi \left[\sqrt{\alpha_{\hat{x}}} \left(\frac{\psi_x + \psi_v}{\psi_x} \theta + \frac{\psi_v}{\psi_x} s - \hat{x}^*(p, z) \right) \right] \quad (1.31)$$

□

1.6.2 Numerical part

Derivation of continuation utility $V = V(B_2, h, \theta)$. I now derive an expression for continuation utility V under the following assumptions

- (1) there is an infinite number of periods;
- (2) labour productivity A_t and government spending g_t are constant, $A_t \equiv A$ and $g_t \equiv g$;
- (3) for $t = 1$ and $t = 2$, the economy is as described in Section 2 except that the government's budget constrain in the second period must be modified to allow for the fact that the government can now borrow, so there exists some B_2 ;
- (4) the government has commitment in all periods except for period $t = 2$;
- (5) if the government defaults in period $t = 2$, the economy experiences an output loss of size θ for T periods, starting from $t = 2$;
- (6) the government inherits a stock of debt B_0 priced at $p_0 = \beta$.

To derive an expression for government continuation utility V , consider the Ramsey problem of a government with commitment and an initial debt stock equal to B_0 :

$$\begin{aligned}
 & \max_{\{C_t, N_t, B_t, \tau_t\}_{t=1}^{\infty}} \sum_{t=1}^{\infty} \beta^{t-1} \left(C_t - \frac{1}{\nu} N_t^{\nu} \right) \\
 & \text{subject to} \\
 & g + \frac{B_{t-1}}{p_{t-1}} \leq w_t \tau_t N_t + B_t \\
 & C_t + g \leq Y_t \\
 & N_t = w_t^{\frac{1}{\nu-1}} (1 - \tau_t)^{\frac{1}{\nu-1}} \\
 & Y_t = A N_t \\
 & w_t = A \quad \text{and} \quad p_t = \beta \quad \text{for all } t \geq 0
 \end{aligned}$$

Re-writing the problem in direct form, one obtains:

$$\begin{aligned}
 & \max_{\{B_t, \tau_t\}_{t=1}^{\infty}} \sum_{t=1}^{\infty} \beta^{t-1} \left(A^{\frac{\nu}{\nu-1}} (1 - \tau_t)^{\frac{1}{\nu-1}} - g - \frac{1}{\nu} A^{\frac{\nu}{\nu-1}} (1 - \tau_t)^{\frac{\nu}{\nu-1}} \right) \\
 & \text{subject to} \\
 & g + \frac{B_{t-1}}{\beta} \leq A^{\frac{\nu}{\nu-1}} \tau_t (1 - \tau_t)^{\frac{1}{\nu-1}} + B_t
 \end{aligned}$$

The optimality conditions for this problem are:

$$\begin{aligned} \{\tau_t\}: \quad \lambda_t &= \beta^{t-1} \frac{\tau_t}{\nu} \left(\frac{\nu-1}{\nu} - \tau_t \right)^{-1} \\ \{B_t\}: \quad \lambda_t &= \frac{\lambda_{t+1}}{\beta} \end{aligned}$$

where $\lambda_t \geq 0$ is the multiplier on the government's period budget constraint. Combining the first order conditions, one obtains that taxes and borrowing must be constant, so $B_t \equiv B_0$. For any level of initial borrowing B_0 , the constant tax rate, $\tau(B_0)$, can be found as the solution to the government's period budget constraint:

$$A^{\frac{\nu}{\nu-1}} \tau (1-\tau)^{\frac{1}{\nu-1}} = g + \frac{1-\beta}{\beta} B_0$$

subject to the constraint that $\tau < \frac{\nu-1}{\nu}$. Note that $\tau(B_0)$ is increasing in B_0 , since

$$\frac{d\tau}{dB_0} = A^{-\frac{\nu}{\nu-1}} (1-\tau)^{-\frac{1}{1-\nu}} \left(1 - \frac{1}{\nu-1} \frac{\tau}{1-\tau} \right)^{-1} \frac{1-\beta}{\beta}$$

and the expression in parentheses is positive for $\tau < \frac{\nu-1}{\nu}$. Social welfare can be written as:

$$\mathcal{W}(B_0) \equiv \frac{A^{\frac{\nu}{\nu-1}}}{1-\beta} \frac{\nu-1}{\nu} [1-\tau(B_0)]^{\frac{\nu}{\nu-1}} + \frac{B_0}{\beta}$$

Continuation utility V can therefore be written as a function of B_2 , h and θ :

$$V(B_2, h, \theta) = \bar{V}(B_2) - v(h, \theta)$$

where $\bar{V}(B_2)$ is defined as $\bar{V}(B_2) \equiv \mathcal{W}(B_2)$ and the function $v(h, \theta)$ is such that:

$$v(h, \theta) = \frac{1}{\beta} \frac{1-\beta^T}{1-\beta} \theta \quad \text{if } h > 0 \quad \text{and } 0 \text{ otherwise}$$

Note that

$$\frac{\partial V(B_2, h, \theta)}{\partial B_2} = \frac{d\bar{V}(B_2)}{dB_2} = -\frac{A^{\frac{\nu}{\nu-1}}}{1-\beta} [1-\tau(B_2)]^{\frac{\nu}{\nu-1}-1} \frac{d\tau}{dB_2} + \frac{1}{\beta}$$

□

The function $\bar{V}(B_2)$ is decreasing in B_2 . To show that continuation utility is de-

creasing in B_2 , re-write \bar{V} as:

$$\bar{V}(B_2) = \frac{1}{1-\beta} \left(A^{\frac{\nu}{\nu-1}} (1-\tau(B_2))^{\frac{1}{\nu-1}} - g - \frac{1}{\nu} A^{\frac{\nu}{\nu-1}} (1-\tau(B_2))^{\frac{\nu}{\nu-1}} \right)$$

and differentiate with respect to B_2 to obtain:

$$\frac{d\bar{V}(B_2)}{dB_2} = -\frac{1}{1-\beta} \frac{A^{\frac{\nu}{\nu-1}}}{\nu-1} (1-\tau(B_2))^{\frac{1}{\nu-1}} \left[\frac{\tau(B_2)}{1-\tau(B_2)} \right] \frac{d\tau}{dB_2} < 0$$

□

Government problem (second period) and default rule. The government's problem in the second period is therefore:

$$\begin{aligned} \max_{B_2, \tau_2, h} \quad & A^{\frac{\nu}{\nu-1}} (1-\tau_2)^{\frac{1}{\nu-1}} - g - \frac{1}{\nu} A^{\frac{\nu}{\nu-1}} (1-\tau_2)^{\frac{\nu}{\nu-1}} + \beta V(B_2, h, \theta) \\ \text{subject to} \quad & \\ & g + (1-h) \frac{B_1}{p_1} \leq A^{\frac{\nu}{\nu-1}} \tau_2 (1-\tau_2)^{\frac{1}{\nu-1}} + B_2 \end{aligned}$$

which returns optimality conditions:

$$\begin{aligned} \{\tau_2\} : \quad & \lambda_2 = \frac{\tau_2}{\nu} \left(\frac{\nu-1}{\nu} - \tau_2 \right)^{-1} \\ \{B_2\} : \quad & \lambda_2 = -\beta \frac{d\bar{V}}{dB_2} \end{aligned}$$

Now notice that:

$$\begin{aligned} -\beta \frac{\partial V(B_2, h, \theta)}{\partial B_2} &= \left(1 - \frac{1}{\nu-1} \frac{\tau}{1-\tau} \right)^{-1} - 1 \\ &= \frac{\tau}{\nu} \left(\frac{\nu-1}{\nu} - \tau \right)^{-1} \end{aligned}$$

so it must be the case that $\tau_2(B_2) = \tau(B_2)$. It follows that the second period tax rate satisfies:

$$A^{\frac{\nu}{\nu-1}} \tau (1-\tau)^{\frac{1}{\nu-1}} = g + \frac{1-\beta}{\beta} B_2$$

which implies that second period borrowing in turn is given by:

$$B_2 = \beta(1-h) \frac{B_1}{p_1}$$

As a result, for a given haircut h second period welfare can be written as:

$$\frac{A^{\frac{\nu}{\nu-1}}}{1-\beta}(1-\tau_2)^{\frac{1}{\nu-1}} - g - \frac{1}{\nu} \frac{A^{\frac{\nu}{\nu-1}}}{1-\beta}(1-\tau_2)^{\frac{\nu}{\nu-1}} - \frac{1-\beta^T}{1-\beta} \theta \mathbf{1}\{h > 0\}$$

Welfare is decreasing in liabilities. More specifically,

$$\begin{aligned} \frac{\mathcal{W}_2}{d\frac{B}{p}} &= -\frac{A^{\frac{\nu}{\nu-1}}}{1-\beta} \left(\frac{1}{\nu-1}(1-\tau_2)^{\frac{1}{\nu-1}-1} - \frac{1}{\nu-1}(1-\tau_2)^{\frac{\nu}{\nu-1}-1} \right) \frac{d\tau^2}{d\frac{B}{p}} \\ &= -(1-\tau_2)^{\frac{1}{\nu-1}} \frac{A^{\frac{\nu}{\nu-1}}}{\nu-1} \frac{1}{1-\beta} \left(\frac{\tau_2}{1-\tau_2} \right) \frac{d\tau^2}{d\frac{B}{p}} \\ &= -(1-\tau_2)^{\frac{1}{\nu-1}} \frac{A^{\frac{\nu}{\nu-1}}}{\nu-1} \left(\frac{\tau_2}{1-\tau_2} \right) (1-h) A^{-\frac{\nu}{\nu-1}} (1-\tau_2)^{-\frac{1}{\nu-1}} \left(1 - \frac{\tau_2}{1-\tau_2} \frac{1}{\nu-1} \right)^{-1} \\ &= -\frac{1}{\nu-1} \frac{\tau_2}{1-\tau_2} (1-h) \left(1 - \frac{\tau_2}{1-\tau_2} \frac{1}{\nu-1} \right)^{-1} \\ &= -\frac{\tau_2(1-h)}{\nu \left(\frac{\nu-1}{\nu} - \tau_2 \right)} \end{aligned}$$

Given that the costs of default do not depend on the haircut h , when the government defaults it does so at the highest possible rate, $h = \eta$. The government then defaults if:

$$\theta < \frac{A^{\frac{\nu}{\nu-1}}}{1-\beta^T} \left[(1-\tau_2^D)^{\frac{1}{\nu-1}} \left(1 - \frac{1-\tau_2^D}{\nu} \right) - (1-\tau_2^{ND})^{\frac{1}{\nu-1}} \left(1 - \frac{1-\tau_2^{ND}}{\nu} \right) \right] \equiv \theta^*$$

For $\theta > \theta^*$, the government does not default, and for $\theta = \theta^*$ the government is indifferent. Without loss of generality (because for a continuous random variable $\Pr\{X \leq x\} = \Pr\{X < x\}$), I assume that an indifferent government defaults. Since the second period tax rate τ_2 is a function of government liabilities, B_1/p_1 , the threshold is also a function of liabilities, $\theta^*(B_1/p_1)$. However, since equilibrium borrowing B_1 is a function of the equilibrium price, we have that the threshold is a function of the price only, $\theta^*(p_1)$. One can then write the optimal haircut as:

$$h = \eta \text{ if } \theta \leq \theta^*(p_1) \quad \text{and} \quad h = 0 \text{ if } \theta > \theta^*(p_1)$$

which says that the government follows a threshold default rule. \square

Proof that θ^ is decreasing in $\frac{B}{p}$.* The derivative of the threshold with respect to li-

abilities is given by:

$$\frac{\mathcal{W}_2}{d\frac{B}{p}} = \frac{1 - \beta}{1 - \beta^T} \left(\frac{\tau_2^D \eta}{\nu \left(\frac{\nu-1}{\nu} - \tau_2^D \right)} + \frac{\tau_2^{ND}}{\nu \left(\frac{\nu-1}{\nu} - \tau_2^N \right)} - \frac{\tau_2^D}{\nu \left(\frac{\nu-1}{\nu} - \tau_2^D \right)} \right) > 0$$

and it is positive since $\tau_2 < \frac{\nu-1}{\nu}$ and $\frac{x}{\frac{\nu-1}{\nu} - x}$ is an increasing function and $\tau_2^{ND} > \tau_2^D$. \square

Ramsey problem. It follows from the above that the government's Ramsey problem is given by:

$$\max_{B_1, \tau_1} \left\{ A^{\frac{\nu}{\nu-1}} (1 - \tau_1)^{\frac{1}{\nu-1}} \left(1 - \frac{1 - \tau_1}{\nu} \right) - \frac{g}{1 - \beta} \right. \\ \left. + \frac{\beta}{1 - \beta} \int_{\theta} \left[A^{\frac{\nu}{\nu-1}} (1 - \tau_2)^{\frac{1}{\nu-1}} \left(1 - \frac{1 - \tau_2}{\nu} \right) - (1 - \beta^T) \theta \mathbf{1}\{h > 0\} \right] f(\theta|p) d\theta \right\}$$

subject to

$$p_1 \in \hat{P}(\theta, s; B)$$

$$g + \frac{B_0}{\beta} \leq w_1^{\frac{\nu}{\nu-1}} \tau_1 (1 - \tau_1)^{\frac{1}{\nu-1}} + B_1$$

$$A^{\frac{\nu}{\nu-1}} \tau_2 (1 - \tau_2)^{\frac{1}{\nu-1}} = g + (1 - h) \frac{B_1}{p_1}$$

$$h = \eta \text{ if } \theta \leq \theta^*(p_1) \quad \text{and} \quad h = 0 \text{ if } \theta > \theta^*(p_1)$$

where both B_1 and τ_1 are functions of the equilibrium price p_1 , $B_1 = B_1(p_1)$ and $\tau_1 = \tau_1(p_1)$. \square

1.6.3 Additional figures

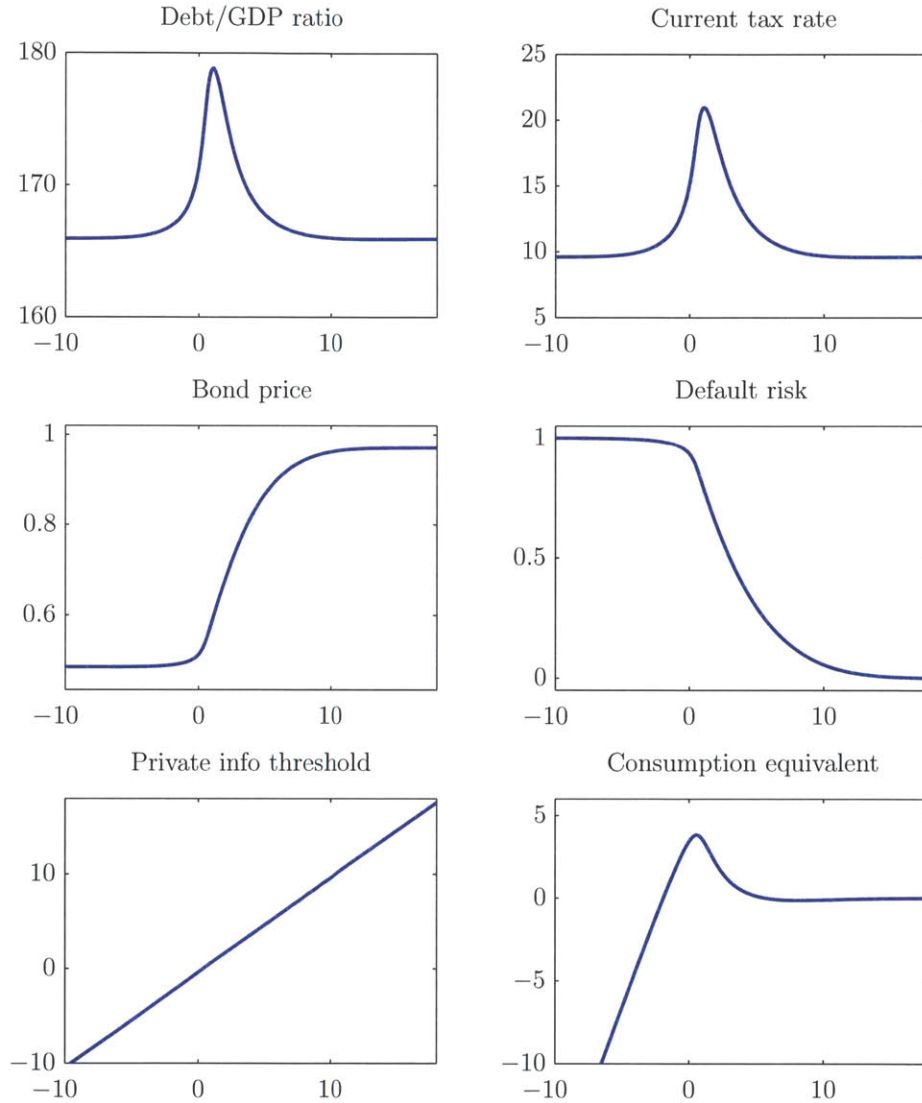


Figure 1-11: Equilibrium of the model as a function of the endogenous public signal z . Given a level of expected welfare, $\mathcal{W}(z)$, the consumption equivalent is computed as the present value of an infinite stream of consumption losses that would return $\mathcal{W}(z)$ as equilibrium welfare under commitment, $CE(z) \equiv \mathcal{W}^C - \mathcal{W}(z)$.

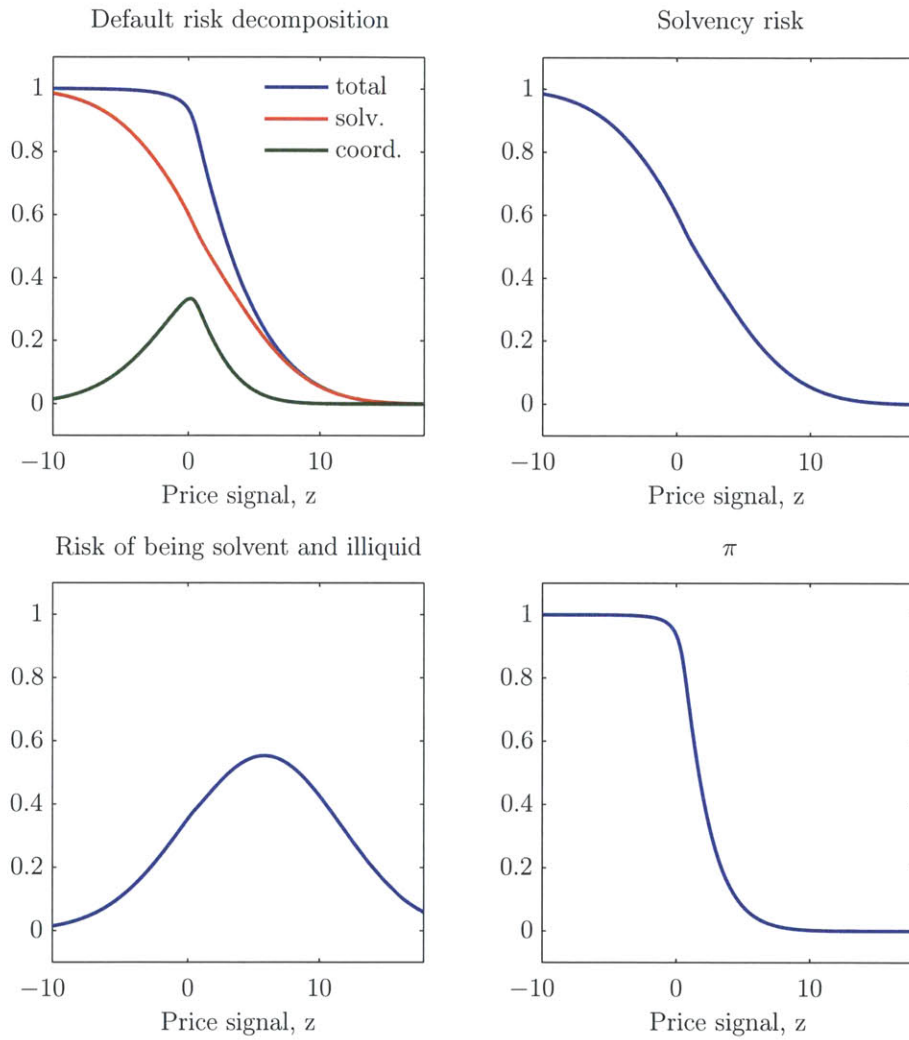


Figure 1-12: Risk decomposition for the model as a function of the endogenous public signal z .

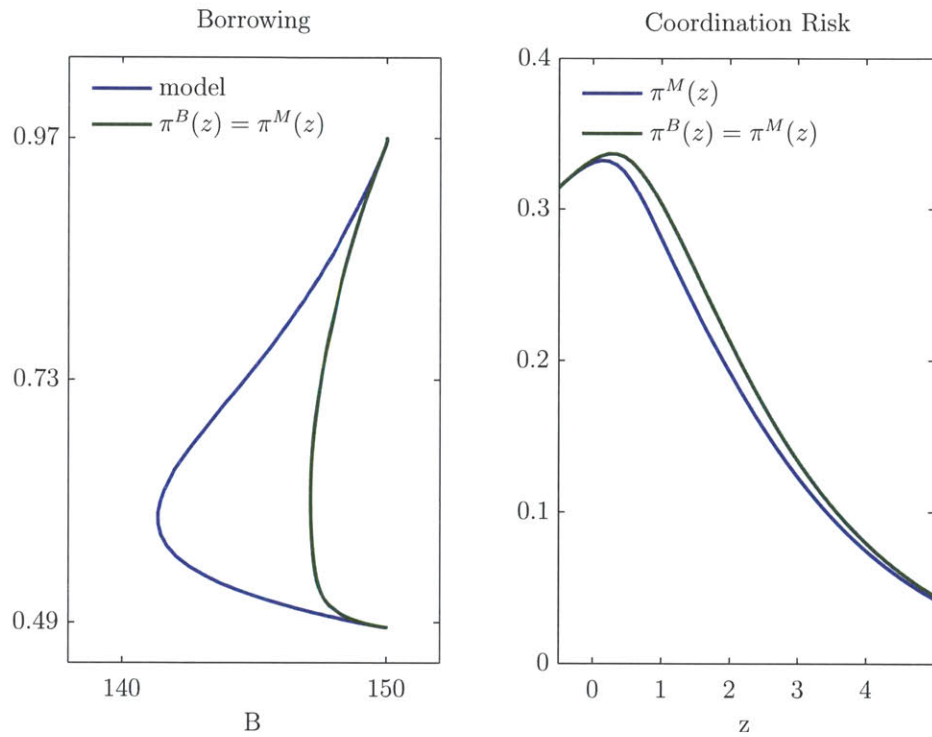


Figure 1-13: Baseline comparison with the exogenous coordination benchmark. Equilibrium borrowing B as a function of the equilibrium price p (left) and equilibrium coordination risk (right) for different exogenous borrowing schedules. The blue lines correspond to the baseline model. The red lines refer to the benchmark with exogenous coordination and varying π^B , $\pi^B(z) \equiv \pi^M(z)$.

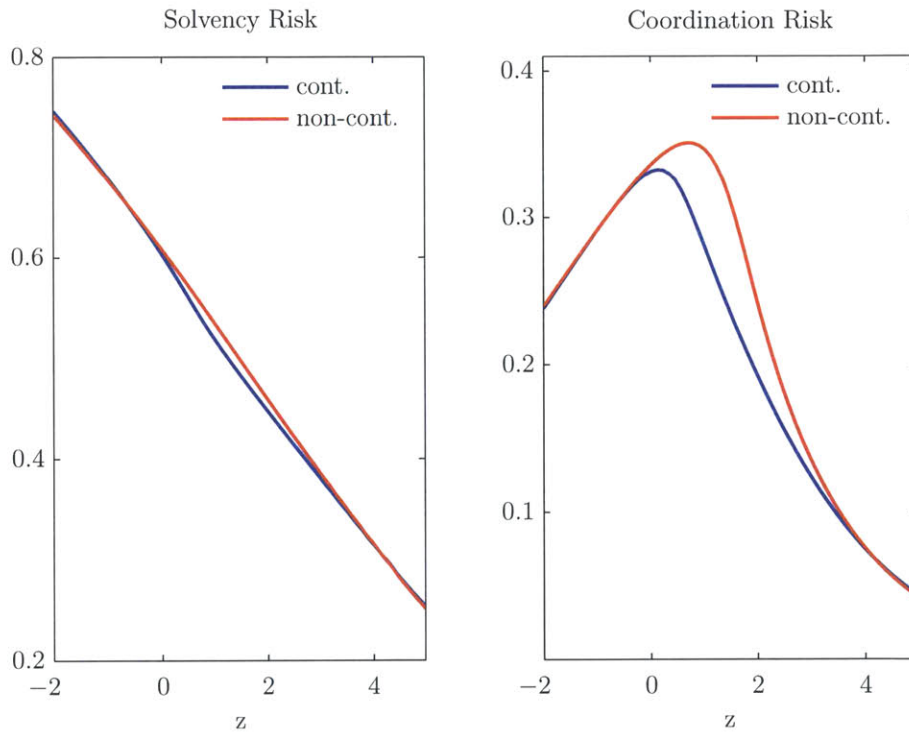


Figure 1-14: Risk decomposition as a function of the endogenous public signal z (right). The blue lines correspond to the model. The red lines represent the case of a government who cannot choose elastic borrowing schedules but must commit to a borrowing level instead.

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Chapter 2

Manipulation and the price of debt

Government manipulation of public data, public statistics, and information is widely observed around the world. This kind of incidents range from outright lying and misreporting to creative accounting where innovative ways of characterizing income, assets and liabilities take place. Occasionally, revelation of such manipulation has dire consequences, raising financing costs for the manipulating government and even marking the beginnings of major crises. The recent Greek case constitutes an example of such dynamics where the 10-year Greek government bond yields rose by 1.2 percentage point within two months of the Finance Minister George Papaconstantinou's announcement that the budget deficit was expected to be as high as 10 percent instead of the 3.7 that had been announced earlier (see Fig. 2-1).

Such episodes of manipulation are observed frequently in a wide variety of countries and can be quantitatively significant as measured by the magnitude of the revision to the debt and deficit data. Table 2.2 compiles a list of country cases with a breach of the Misreporting Guidelines and/or of Article VIII, Section 5 of the International Monetary Fund (IMF) and finds that misreporting, delayed reporting or nonreporting of information required by the IMF occurs in countries with different degrees of development though perhaps it occurs more often in the developing world. The table lists 23 such incidents since 2000, most of which relate to the fiscal soundness and indebtedness of the government.

On the magnitude of the revisions, Figure 2-2 takes the Greek case as an example and shows that various revisions were made to the past Greek general government balances in the period 1997-2007, almost all downward, and were quantitatively significant. This figure plots different releases of the World Economic Outlook data of the IMF updated regularly twice a year. Since we are only interested in the historical data as opposed to the forecasts, each of the lines in the figure end in the year prior to the release of the data. Looking at different releases in chronological

order, one can observe that all revisions (except April 2006 revision to the 2001 deficit) are downward. The magnitude of the revisions vary but they do reach almost 5% of GDP in April 2005 revision of the deficit that prevailed in 2002.¹

Having observed that governments' manipulation of public data occurs fairly frequently in a wide range of countries and sometimes in large magnitudes, we theoretically study the incentives of a government to manipulate. First, we aim to understand whether in an environment where the private agents hold rational expectations - that is, they understand and internalize that the government has access to a manipulation technology - the government will find it optimal to manipulate if it is costly to do so. From the government's perspective, private agents holding rational expectations (RE) implies that it is harder to "fool" them, potentially undermining its desire to manipulate. Hence, manipulation may not arise in equilibrium. The first question we seek to answer is therefore whether there is scope for governments to manipulate effectively, i.e. decrease interest rates and default risk by manipulating public information. Second, we aim to understand how the degree of transparency, access to different manipulation technologies affect manipulation incentives and also whether news that reveal a higher probability of manipulation can generate a sizable increase in the interest rate faced by the government when it tries to borrow from the private sector.

In order to address these questions, we build a model with two types of economic agents, a government and a mass-one continuum of risk-neutral private sector investors. The government seeks to borrow an exogenous amount from the private sector by issuing a one period discount bond to finance a risky project whose return is known only to the government. Hence, the government and the private sector have asymmetric information about the return of the project which we refer to as the fundamentals of the economy. The government bond is risky because we assume that the government has limited commitment and may choose to default depending on the realized interest rate. Each investor decides to lend to the government or not. The price of the bond is endogenously determined and plays an informational role by aggregating private signals.

Since in models with limited commitment private sector agents face strategic complementarities and thus a coordination problem, there may be multiple equilibria under the assumption of common knowledge. We therefore introduce dispersed

¹This figure does not differentiate between data revisions due to revelation of manipulation or other reasons such as methodological changes in compilation of statistics. The fact that almost all revisions are downwards makes it unlikely that methodological changes are the only driver. In addition, January 2010 report of the European Commission finds "... additional evidence that the problems are only partly of a methodological nature and would largely lie beyond the statistical sphere."

information and use techniques from the global games literature so as to induce price uniqueness. Private sector agents have three kinds of information: idiosyncratic private information, exogenous public information which is potentially manipulated, and endogenous public information conveyed by the financial price. Conditional on such information, they formulate posterior beliefs about the state of the economy and submit demand functions for government bonds.

The manipulation technology is specified as one that allows the the government to bias the mean of the exogenous public signal upwards. The government incurs convex manipulation costs. Even though the manipulation technology is fully understood and manipulation as a function of the fundamentals is internalized by the private sector, because of asymmetric information of the fundamentals between the private sector and the government, the actual amount of manipulation is unknown and the private sector forms expectations about it.

First, we show that there cannot be any equilibrium in which the government does not manipulate for any value of the fundamental. The intuition is that if there were an equilibrium in which no government type manipulated and the private investors held naive beliefs consistent with the government not manipulating, a government with a fundamental that is neither too low or too high would find it optimal to deviate from this equilibrium without manipulation. This deviation would deliver a higher expected payoff in the form of higher bond price net of cost of manipulation. Hence, incentives to manipulate arise because the government's payoff depends on the interest rate, which in the class of equilibria we consider is an increasing function of the exogenous public signal.

Having established that manipulation occurs in equilibrium, we next identify and analyze two important forces that affect the incentives to manipulate. The first force is the presence of rational expectations. As discussed above, the fact that the private investors understand and internalize the manipulation technology has a large effect on the degree of manipulation. While the presence of RE implies significantly less manipulation, at least for some government types, it is still not strong enough to eliminate manipulation incentives altogether. For manipulation to be optimal for some government types, it must be the case that the conditional mean of the exogenous public signal is monotonically increasing in the fundamental. This is a key result, since it underpins the monotonicity of the market posterior default belief with respect to the biased signal, and hence, the monotonicity of the bond price.

The second force is the negative externality imposed on any government "type" as a result of manipulation of weaker and stronger types. Manipulation by worse governments imposes an externality because it becomes more likely to be pooled

with them. Similarly, a better government that manipulates can send a strong enough signal such that it is more easily separated from the relatively weaker ones. Our experiments show that this negative externality may be sufficiently strong to increase optimal manipulation relative to a benchmark with naive beliefs, and therefore partially counteract the impact of rational expectations, which tends to decrease manipulation.

The relative strength of these two forces sheds light into why some government types are better off with the manipulation technology while others would prefer to commit not to manipulate if they could. We show that when governments have access to the manipulation technology, the ones with worse fundamentals face higher interest rates than in the case without manipulation, despite also being the types with the strongest manipulation incentives. While these governments would pay to obtain a commitment device, the governments with better fundamentals enjoy lower interest rates and would pay for obtaining the manipulation technology instead. When we decompose manipulation incentives for both “winners” and “losers” into rational expectations and negative externality effects, we find that while for the winners the externality effect partially offsets the rational expectations effect, both effects work to decrease manipulation for losers. In this sense, the losers endure the externality, while the winners compensate for it.

In our comparative statics analysis, we find that the incentives to manipulate disappear when the exogenous public signal is sufficiently precise. As the quality of public information becomes arbitrarily good, fundamentals uncertainty disappears. Hence, the market can perfectly undo any attempt at manipulating, and it no longer pays for the government to do so. This result underscores the importance of monitoring and surveillance of government statistics by independent authorities as a means to discourage manipulation and foster transparency.

Finally, we analyze two extensions or applications of our framework. First, in a slightly extended model where the government has access to a manipulation technology with an exogenous probability, we examine the impact of “news” that reveal that the probability of the government having access to a manipulation technology is high. The analysis shows that such news can lead to a significant increase in the interest rate faced by the government.

Second, we find that a technology that allows the government to manipulate private information may not result in a significant gain or loss in terms of the effectiveness of manipulation. A priori one may expect that to the extent that public information can be used to foster coordination on better equilibria, it may be the case that manipulating public information is more effective than manipulating pri-

vate information. However, when financial prices are endogenous, as they are in our framework, they work as coordination devices, in addition to aggregating private information. Hence, manipulating private information may not be different than manipulating public information because such manipulation would work through biasing price signals which play a similar role as exogenous public signals.

Our paper relates to two main strands of literature: the broader theoretical literature on coordination games and career concerns models, and the empirical literature on the connection between manipulation and fiscal policy. On the theoretical side, our model is most closely related to Edmond (2011), who studies manipulation in a coordination game with dispersed information. In his paper, the private sector relies solely on private information, which the regime endogenously distorts so as to increase its chances of survival by affecting the size of the attack. In our model, on the other hand, the government affects coordination by distorting public information. More importantly, the coordination game is embedded in a financial market, so manipulation has an indirect impact on the coordination problem of the private sector via the bond price.

Our model also differs from Edmond's in its implications for transparency. He finds that the effectiveness of manipulation increases with the quality of the private information. This follows from the fact that when the signal distribution is highly concentrated, even a small amount of bias can deliver a large change in the size of the attack, which makes manipulation more powerful. In addition, private agents cannot infer the bias and are imperfectly coordinated. In contrast, when we introduce endogenous prices and allow for manipulation of the price distribution, we find that for sufficiently precise public information, manipulation is completely ineffective because the price distribution ceases to be affected by signal bias. It follows that in models of manipulation with dispersed information, the implications of greater transparency vary widely depending on assumptions about the presence of markets.²

Another related paper is Angeletos et al. (2006) in which a government sends a signal to the private sector about the value of the fundamental by selecting policy, thereby affecting the coordination problem of the market and re-introducing the possibility of multiple equilibria. In our model, multiplicity is also a possibility, but for different reasons. As first pointed out by Angeletos and Werning (2006), the presence of an endogenous asset price has the potential to re-introduce equilibrium

²Note that our transparency result would prevail even when the government manipulated private information rather than exogenous public information. This is because private information is aggregated into the price, so private information manipulation is equivalent to manipulating the price signal. As the quality of private information becomes arbitrarily good, so does the quality of the price signal, and the price distribution ceases to depend on the manipulation action because it converges to a spike at the value of the fundamental.

multiplicity by causing asset demand to be backward bending. Since the bond price is negatively correlated with default risk, higher price tends to increase expected returns. This “default effect” may be sufficiently large to offset the negative impact of higher prices on bond demand, thereby causing aggregate bond demand not to be monotonic.

The career concern models of Holmstrom (1999) and Dewatripont et al. (1999) are similar to ours in the sense that they feature a manager that manipulates by providing effort so as to increase her market wage, which is contingent on past performance. There are, however, three important differences in that career concerns models assume symmetric information, they do not feature public signals to help coordination and private sector actions are not strategic complements. Hence, a meaningful comparison of our framework with the career concern models require understanding how manipulation incentives would be affected if each of the aforementioned features were to be introduced in career concerns model. Section 6 conducts such analysis.

Our paper is also related to the literature on global games with endogenous prices. It follows Hellwig et al. (2006) and Tarashev (2007) by embedding the coordination problem in a financial market rather than featuring it as a subsequent stage as in Angeletos and Werning (2006). As in those papers, the financial price plays a coordination role for the private sector. Finally, we follow Metz (2002), Heinemann and Illing (2002) and Morris and Shin (2004) in modeling transparency as an improvement in the quality of information as captured by its precision.

On the empirical front, our paper relates to Koen and van den Noord (2005) in that these authors take a comprehensive stock of the observed “gimmickry” episodes in Europe and also clarify nuances of various types of manipulation such as one-off measures and creative accounting. Weber (2012) utilizes information from stock-flow adjustments defined as discrepancies between debt and the budget deficit. While imperfect, since these adjustments can arise from non-manipulation related reasons such as the realization of contingent liabilities or valuation effects, stock-flow adjustments can provide a broad idea about the extent of manipulation. In her study, Weber (2012) finds that less transparent countries tend to have smaller stock-flow adjustments. This is consistent with our finding that higher transparency reduces the incentives of governments to manipulate.

There is a related literature that aims to understand the interaction between fiscal rules and incentives for manipulation. In this literature, Milesi-Ferretti (2004) shows that creative accounting is more likely when the cost of getting caught is smaller, if the cost of sticking to a fiscal rule is high and finally if the rule restricts fiscal policy adjustment to shocks. Consistently with Milesi-Ferretti’s findings, von

Hagen and Wolff (2006) show that the Stability and Growth Pact rules of the E.U. led member governments to use stock-flow adjustments, which may be considered a form of creative accounting.

Finally, an alternative way to relate our paper to the literature is to think about it as one that provides microfoundations to the vast number of studies that assume imperfect information in a macroeconomic context. More specifically, this literature, exemplified by Blanchard et al. (2012), Boz (2009), Boz et al. (2011), Edge et al. (2007), takes as given imperfect information regarding some “fundamental” of a country. One source of this informational friction could be the government choosing to create such an imperfect information environment. In this sense, our paper takes a step back and shows that government manipulation can be an equilibrium outcome and can be a justification for the assumption of imperfect information.

2.1 The model

The economy is inhabited by a government and a measure-1 continuum of risk-neutral private sector agents. The government seeks to finance $B(q)$ projects, each of which yields a return equal to θ (fundamentals). The value of θ is not common knowledge. Specifically, while the government observes the θ draw, the private sector does not. The government finances the projects by issuing a bond that trades at price q . The government has limited commitment and it may choose to renege on its past promises after the price has been determined. Defaulting involves a proportional loss of size $\kappa \in (0, 1)$ for the government.

Timing is as follows. At the beginning of the period, nature draws a value of the fundamental θ . The government observes θ and chooses a hidden manipulation schedule $a(\theta) \geq 0$. The manipulation action a distorts the mean of a public signal y and it involves a cost $C(a) \geq 0$, which is assumed to be convex and such that $C(a) = C'(a) = 0$. After the government has picked its hidden action, each private sector agent receives two private signals $(x_{1,i}, x_{2,i})$ and a public signal y about θ . Conditional on this information, a private sector agent i chooses whether or not to participate in the financial market by submitting a price-contingent bond demand schedule. Individual bond demand schedules are then aggregated and an equilibrium bond price is selected to ensure market clearing. Once the bond market closes, the government chooses a default rate $h \in [0, \eta]$, with $0 < \eta < 1$. The timing is summarized in Fig. 2-3.

The government observes θ . The private sector, on the other hand, shares a common degenerate prior about θ which is uniform over the real line. Agents receive

two private signals about θ

$$x_{1,i} = \theta + \varepsilon_{1,i} \quad (2.1)$$

$$x_{2,i} = \theta + s + \varepsilon_{2,i} \quad (2.2)$$

where all three shocks $(s, \varepsilon_1, \varepsilon_2)$ are independent Gaussian random variables with mean zero and standard deviations given by $(\sigma_s, \sigma_{x,1}, \sigma_{x,2})$, respectively. Note that the shock s is meant to capture correlated movements in private sector beliefs. Also observe that there exists a linear sufficient statistic for private information, $x_i \equiv \omega x_{1,i} + (1 - \omega)x_{2,i}$, with $\omega \equiv \alpha_{x,1}/(\alpha_{x,1} + \alpha_{x,2})$, $\alpha_{x,1} \equiv \sigma_{x,1}^{-2}$ and $\alpha_{x,2} \equiv \sigma_{x,2}^{-2}$. Conditional on the vector (θ, s) , the sufficient statistic x_i is Gaussian with mean $\theta + (1 - \omega)s$ and precision $\alpha_x \equiv [\omega^2 \sigma_{x,1}^2 + (1 - \omega)^2 \sigma_{x,2}^2]^{-1}$.

The private sector also observes a potentially biased public signal

$$y = \theta + a + \varepsilon_y \quad (2.3)$$

where the shock ε_y is also Gaussian with mean zero and standard deviation σ_y . Moreover, ε_y is independent of $(s, \varepsilon_{1,i}, \varepsilon_{2,i})$ for all $i \in [0, 1]$.

Private sector agents also take into account the information content of the bond price. The bond market clearing condition $B(q) = D(\theta, q, y, s)$ implicitly defines a price correspondence $Q(y, \theta, s)$, so each realization of the equilibrium price q is informative about θ .³ We will show later on that the assumptions we have made about private information enables us to focus on equilibria such that $Q(y, \theta, s) = Q(y, z)$, so the price correspondence depends on the fundamental θ and the correlated noise s only through a linear combination z

$$z = \theta + \lambda s \quad (2.4)$$

which works as an endogenous public Gaussian signal about θ .

The government chooses $h \in [0, \eta]$ so as to maximize its ex-post payoff, which is then given by

$$U_G(\theta, q, B(q)) - C(a) = \max_{h \in [0, \eta]} \left([1 - k(h)]\theta - \frac{1 - h}{q} \right) B(q) - C(a) \quad (2.5)$$

Here, $C(a)$ denotes the cost of manipulation, which has to be paid regardless of the outcome. The function $k(h) = \kappa \mathbb{I}\{h > 0\}$ represents the cost of defaulting.

³We provide a formal characterization of bond demand $D(\theta, q, y, s)$ (see equation (2.10)) and of the equilibrium price correspondence $Q(y, \theta, s, B(q))$ (see equation (2.11)) later in the paper.

Ex-ante, the government must take into account market clearing, which means internalizing that q is selected from the equilibrium price correspondence $Q(y, \theta, s)$. The ex-ante government's payoff is hence given by

$$\mathbb{E}_{(y,s)}\{U_G[\theta, Q(y, \theta, s), B(q)]|\theta, a\} - C(a) \quad (2.6)$$

where the expectation is taken with respect to the joint distribution of the public signal y and the correlated shock s conditional on θ and a . This distribution is a bivariate Gaussian with mean $[\theta + a, 0]$ and variance-covariance matrix $\Sigma_{y,s} = \begin{bmatrix} \alpha_y & 0 \\ 0 & \alpha_s \end{bmatrix}$. Here, $\alpha_y \equiv \sigma_y^{-2}$ and $\alpha_s \equiv \sigma_s^{-2}$ denote the precisions of the public signal and of the correlated shock, respectively.

Private sector agents have a unitary endowment. They have the option to store it or to spend it on government bonds. Storage yields a safe return of 1 for each unit invested. As we have seen, government bonds are risky, and they yield $(1 - h)/q$. Letting b_i denote the bond investment of agent i , her ex-post payoff is given by

$$u(q, h, b_i) = \beta \left[\frac{1 - h}{q} b_i + (1 - b_i) \right] \quad (2.7)$$

Here, $\beta \leq 1$ denotes the discount factor of the private sector. Agent i 's ex-ante payoff is then simply

$$U(x_i, y, q, b_i) = \mathbb{E}_\theta [u(q, h, b_i)|x_i, y, q] \quad (2.8)$$

where the expectation is taken with respect to the distribution of the fundamental θ conditional on the private information x_i , the potentially manipulated public signal y and the endogenous price signal q .

The bond market clears when bond supply $B(q)$ equals bonds demand

$$B(q) = D(\theta, q, y, s) \quad (2.9)$$

where aggregate bond demand is defined as

$$D(\theta, q, y, s) = \int_{-\infty}^{+\infty} b(x, y, q) \sqrt{\alpha_x} \phi[\sqrt{\alpha_x}(\theta + (1 - \omega)s - x)] dx \quad (2.10)$$

As anticipated earlier, the bond market clearing condition implicitly defines an equilibrium price correspondence

$$Q(y, \theta, s) = \{q : B(q) = D(\theta, q, y, s)\} \quad (2.11)$$

This is simply the set of bond prices that are consistent with market clearing for a given value of the fundamental θ , the correlated shock s and the realization of the public signal y .

2.2 Equilibrium

2.2.1 Equilibrium definition.

The equilibrium is defined for a given borrowing function $B : (\underline{q}, \bar{q}) \rightarrow [0, 1]$ and a given manipulation schedule $a(\theta)$. Note that $\underline{q} \equiv \beta(1 - \eta)$ and $\bar{q} \equiv \beta$.

Definition 5 (Equilibrium). A symmetric perfect Bayesian equilibrium is a posterior belief for the private sector $\pi[\theta|x, y, q, a(\cdot)]$, individual lending decisions $b(x, y, q)$, a bond price correspondence $Q[\theta, y, s; a(\cdot)]$ and a default decision for the government $h(\theta, q)$ such that

1. for any q that arises along the equilibrium path, the posterior density $\pi[\theta|x, y, q, a(\cdot)]$ is formulated according to Bayes' Law given the manipulation schedule $a(\theta)$;
2. for any q that arises along the equilibrium path, the lending decision $b(x, y, q)$ maximizes private sector agents' expected utility as given by (2.8) and computed according to $\pi(\theta|x, y, q, a(\cdot))$;
3. the price correspondence $Q[\theta, y, s; a(\cdot)]$ is defined as in (2.11);
4. $h(\theta, y)$ maximizes the ex-post utility of the government as given by the right hand side of (2.5).

For any government type $\theta \in \mathbb{R}$, the problem then amounts to selecting a manipulation action $a(\theta)$ that maximizes its expected equilibrium utility, equation (2.6). Note that while the manipulation action selected by a type- θ government has an impact on the equilibrium price correspondence via its contribution to the manipulation function $a(\cdot)$, the government takes the beliefs of the market about manipulation, incorporated into the bond price, as given. The government takes the equilibrium price as given and it does not behave like a monopolist.

Definition 6 (Optimal manipulation). The optimal manipulation schedule $a(\cdot)$ is a function

$$\begin{aligned} a : \mathbb{R} &\rightarrow \mathbb{R}_+ \\ \theta &\mapsto a(\theta) \end{aligned}$$

such that for all $\theta \in \mathbb{R}$, $a(\theta)$ is a solution to the government's problem

$$\max_{a \geq 0} \mathbb{E}_{(y,s)} \{U_G[\theta, q, B(q)|\theta, a] - C(a) \quad \text{with} \quad q \in Q[\theta, y, s; a(\cdot)] \quad (2.12)$$

taking as given the beliefs of the market about the manipulation function $a(\theta)$.

We choose the function $B(q)$ so that the equilibrium interest rate correspondence depends on (y, θ, s) only through the vector (y, z) , where z is a linear combination as given by (2.4). Note that given y , z works as a sufficient statistic for the bond price q . This enables us to write the posterior belief of the private sector in a tractable form. To this end, we make the following assumption.

Assumption 1. *Assume that the borrowing function is given by $B(q) = \Phi(\gamma)$ with $\gamma \in \mathbb{R}$.*

Under Assumption 1, government borrowing is inelastic. In principle, we could have allowed borrowing to depend on the price q while still obtaining a tractable expression for the equilibrium price correspondence. We choose not to do so because, as shown by Hellwig et al. (2006), when borrowing is allowed to be elastic the aggregate demand for bonds is more likely to be backward bending (due to the “equilibrium effect”), thereby making it harder to identify simple conditions for price uniqueness under manipulation. In practice, what happens is that the marginal signal x^* becomes smaller (so the marginal agent is more pessimistic) for higher q , which tends to increase bond demand thereby reinforcing the positive default effect of higher prices (lower default risk). To get around these issues, we simply assume that borrowing is inelastic.

Moreover, we focus on threshold equilibria. These are equilibria such that for any pair (y, q) , $b(x, y, q) = 0$ if $x \leq x^*(y, q)$ and $b(x, y, q) = 1$ otherwise. In addition, for any pair (θ, q) , the default rate $h(\theta, q) = \eta$ if $\theta \leq \theta^*(q)$ and $h(\theta, q) = 0$ otherwise. Under these restrictions, an equilibrium is fully characterized by five objects: an optimal manipulation action for the government $a(\theta)$, a default threshold for the government $\theta^*(q)$, a private belief for the private sector $\pi(\theta|x, y, z)$, a lending threshold for the private sector $x^*(y, q)$ and a price correspondence $Q(y, z)$.

Finally, we only consider monotone selections from the price correspondence $Q(y, z)$. To that end, we make the following assumption.

Assumption 2 (Price uniqueness with manipulation). *Assume that $1 < \kappa\beta \left(\frac{1-\eta}{\eta}\right)^2$.*

We show in the Appendix that this assumption is sufficient to ensure that the price correspondence is single-valued, so we do not have to worry about selection issues.

2.2.2 Equilibrium characterisation.

Since default costs are fixed, if the government defaults it does so at the maximum possible rate, η . By (2.5), $h(\theta, q) = \eta$ as long as

$$\theta \leq \frac{\eta}{\kappa} \frac{1}{q} \equiv \theta^*(q) \quad (2.13)$$

which shows that the default threshold depends on the bond price via the interest rate $1/q$.

Consider now the bond market clearing condition. Under the restriction that $b = 0$ if $x \leq x^*(y, q)$, the demand for bonds is given by

$$D(\theta, q, y, s) = \Phi[\sqrt{\alpha_x}(\theta + (1 - \omega)s - x^*(y, q))] \quad (2.14)$$

As a result, by Assumption 1 the market clearing condition can be written as

$$x^*(y, q) + \frac{\gamma}{\sqrt{\alpha_x}} = \theta + (1 - \omega)s \equiv z \quad (2.15)$$

which establishes that, given common knowledge of the functions $x^*(\cdot, \cdot)$ and $B(\cdot)$, observing the vector (y, q) is equivalent to observing a signal z , where z is a Gaussian random variable with mean θ and precision $\alpha_z \equiv \alpha_s/(1 - \omega)^2$. The posterior default belief can thus be written as

$$\begin{aligned} & \Pi[\theta^*(q), x, y, z, a(\cdot)] \\ &= \frac{\int_{-\infty}^{\theta^*(q)} \phi \left[\sqrt{\alpha_{x,z}} \left(u - \delta x - (1 - \delta)z + \frac{\delta\gamma}{\sqrt{\alpha_x}} \right) \right] \phi[\sqrt{\alpha_y}(u + a(u) - y)] du}{\int_{-\infty}^{+\infty} \phi \left[\sqrt{\alpha_{x,z}} \left(u - \delta x - (1 - \delta)z + \frac{\delta\gamma}{\sqrt{\alpha_x}} \right) \right] \phi[\sqrt{\alpha_y}(u + a(u) - y)] du} \end{aligned} \quad (2.16)$$

Here, δ represents the weight given to private information in an inference problem about θ conditional on x and z , $\delta \equiv \alpha_x/\alpha_{x,z}$, with $\alpha_{x,z} \equiv \alpha_x + \alpha_z$.

The following Lemma and Corollary establish that the posterior default belief of the market decreases for higher values of information, regardless of the source.

Lemma 1. *Suppose market beliefs are consistent with $\theta + a(\theta)$ being monotonically increasing in θ . Then the posterior default belief of any private agent is monotonically decreasing in y .*

Corollary 1. *The posterior default belief of the market decreases in x and in z .*

There remains to characterize the optimal price correspondence and the private

signal threshold $x^*(y, q)$. Note that by market clearing,

$$x^*(y, q) = z - \frac{\gamma}{\sqrt{\alpha_x}} \quad (2.17)$$

Also observe that $x^*(q, y)$ must satisfy the indifference condition of the private sector

$$\Pi[\theta^*(q), x^*(y, q), y, z, a(\cdot)] = \tilde{q}(q) \quad (2.18)$$

where $\tilde{q}(q) \equiv \frac{1}{\eta} \left(1 - \frac{q}{\beta}\right)$. Then, substituting in $\xi(z, q)$ for $x^*(y, q)$ from (2.17) into (2.18), one obtains

$$\Pi[\theta^*(q), z - \gamma/\sqrt{\alpha_x}, y, z, a(\cdot)] = \tilde{q}(q) \quad (2.19)$$

that is, an equation in q , y and z only. This equation implicitly defines the price correspondence $Q[y, z, a(\cdot)]$ for any pair $(y, z) \in \mathbb{R}^2$ and any manipulation function $a(\cdot)$.

The price correspondence is always non-empty but it may not be single-valued. As first shown in Hellwig et al. (2006), if the “default effect” of a price increase (the drop in default risk) is large enough to offset the “cost effect” (the fact that bonds are more expensive), bond demand may actually be backward bending. We have the following.

Lemma 2. *The price correspondence is non-empty for all $(y, z) \in \mathbb{R}^2$. Suppose market beliefs are such that conditional mean of the public signal y , $\mathbb{E}[y|\theta] = \theta + a(\theta)$ is monotonically increasing in θ . Then*

- (i) *under Assumption 2, the price correspondence $Q(y, z)$ is single-valued;*
- (ii) *under Assumption 2, the price function $Q(y, z)$ is increasing in y .*

Corollary 2. *Under Assumption 2, the price function $Q(y, z)$ is increasing in z .*

Assumption 2 guarantees that the cost effect always dominates, which gets us a monotonic demand schedule. Coupled with inelastic borrowing, that guarantees price uniqueness. Price uniqueness is also useful to the extent that under uniqueness, the model predicts a positive correlation between fundamentals and bond prices, and thus a negative correlation between fundamentals and interest rates.

For any pair (y, q) such that q arises along the equilibrium path, the private threshold $x^*(y, q)$ can be retrieved as follows. Since the price function is monotonic in z for all y , it can be inverted for all y . As a result, for each pair $(y, q) = [y, Q(y, z)]$ one can retrieve the corresponding z as $z = Q^{-1}(y, q)$. By equation (2.17), then, $x^*(y, q) = z$.

2.2.3 Optimal manipulation.

Our first analytical result is that there exists no equilibrium without manipulation.

Proposition 1 (No equilibrium without manipulation.). *If the government has access to the manipulation technology, there exists no equilibrium such that $a(\theta) = 0$ for all $\theta \in \mathbb{R}$.*

Proposition 1 establishes that at least some government types have an incentive to manipulate when they expect everyone else not to. The proof is by contradiction. It relies on the observation that when the market holds “naive beliefs” such that $a(\theta) = \theta$ for all $\theta \in \mathbb{R}$, the market also believes the mean of y to be monotonically increasing in θ , $\mathbb{E}[y|\theta] = \theta$, which makes the ensuing bond price increasing in y (see Proposition 5). This implies that by choosing $a(\theta) > 0$, which makes high values of y more likely, a type- θ government may be able (provided θ is neither too small nor too large) to increase its expected bond price, and thereby raise its expected payoff gross of the cost of manipulation. If the bond price function $Q(y, z)$ were not increasing in y , this incentive would not be there. Figure 2-4 provides an example of the “optimal deviations” from an equilibrium without manipulation. The continuous blue line in this figure plots the optimal manipulation schedule under the assumption that the market believes $a(\theta) = 0$ for all $\theta \in \mathbb{R}$.

Since there cannot be an equilibrium without manipulation, it is important to understand the manipulation incentives of governments when they expect some other governments to manipulate in equilibrium. For manipulation to be worthwhile, it must be the case that a government can expect to face higher prices by choosing a positive manipulation action which makes large values of y more likely. In order for this to happen, the bond price needs to be an increasing function of y , which in turn requires that the posterior default belief of the market $\Pi[\theta^*(q), z - \gamma/\sqrt{\alpha_x}, y, z]$ be decreasing in y for all q . By Lemma 2, a necessary condition for this monotonicity - and thus a necessary condition for positive manipulation incentives - is that the mean of the public signal y conditional on θ , $\mathbb{E}[y|\theta] = \theta + a(\theta)$, be an increasing function of θ . We prove this result next.

Proposition 2 (Incentives to manipulate). *The conditional mean of the public signal y , $\mathbb{E}[y|\theta] = \theta + a(\theta)$, is monotonically increasing in θ .*

Note that together with Corollary 2, Lemma 2 also ensures a positive correlation between the fundamental θ and the bond price.

Having established that there are incentives to manipulate when the market is rational, we now seek to better understand their drivers. In particular, we are

interested in getting a sense of the impact of rational expectations - the fact that the market rationally takes into account optimal manipulation when formulating beliefs - on the incentives to manipulate.

One may think that a comparison of equilibrium manipulation against the manipulation schedule that would arise with naive beliefs would give us a gauge of the effect of market rationality. Rational expectations should decrease the incentives to manipulate relative to naive expectations, so we may expect governments to manipulate less. However, market rationality is not the only force at play in determining incentives to manipulate. We must also take into account the possibility of negative manipulation externalities.

Let us consider the following thought experiments. First, fix some government type θ , and suppose there are types $\theta' > \theta$ such that $a(\theta') > 0$. Further assume that $a(\theta'') < 0$ for all $\theta'' < \theta$. Then θ suffers from an externality arising from manipulation by the better types. The intuition is that it is now easier for the market to separate out θ from better types upon observing high values of y , since these are more likely to come from the types that manipulate. Let's now suppose the scenario is reversed, so $a(\theta') = 0$ but $a(\theta'') > 0$. This time the negative externality arises from the worse types. It is now easier for the market to pool θ together with worse types upon observing low values of y , since these values are more likely to come from bad types disguising as better types via manipulation. Finally, consider the possibility that $a(\theta') > 0$ and $a(\theta'') > 0$. Then θ suffers a negative externality from both the higher and the lower types. In each scenario, the presence of externalities should push θ towards manipulating, and perhaps to manipulate even more than it would have had if no-one else was distorting the public signal mean.

Given the potential for negative externalities, then, a simple comparison of manipulation with and without naive beliefs is not sufficient to get insights into the relative importance of rational expectations on manipulation incentives. Nonetheless, it is a good starting point. We present this comparison in Figure 2-4. The figure suggests that the "rational expectations effect" dominates the "negative externalities effect" in this particular example, since the manipulation action computed under rational expectations is never larger than the manipulation action computed under naive expectations.

Next, we try to tease the two effects - rational expectations and negative externalities - apart by performing the following experiment. We restrict our attention to the multiplicity region $[\underline{\theta}, \bar{\theta}]$, since Fig. 2-4 suggests this is where the negative externalities effect is potentially strongest, as the difference between optimal manipulation with naive beliefs and with rational beliefs is smallest. We divide this region into

$j = 1, \dots, N$ intervals $[a(j), b(j)]$ such that $a(1) = \underline{\theta}$ and $b(N) = \bar{\theta}$. We compute the optimal manipulation action under the assumption that the cost of manipulation depends on θ . Specifically, we assume that for $\theta \in [a(j), b(j)]$, $C(a, \theta) = C(a)$, but for all $\theta < a(j)$ and all $\theta > b(j)$, $C(a, \theta) \rightarrow +\infty$. As a result, $a(\theta) = 0$ for all $\theta < a(j)$ and all $\theta > b(j)$. This effectively kills negative manipulation externalities arising from types outside the sub-interval $[a(j), b(j)]$. As a result, by comparing $a(\theta)$ for $\theta \in [a(j), b(j)]$ with the corresponding manipulation function computed under the assumption of naive market beliefs we can better isolate the impact of rational expectations on government incentives to manipulate.

The results of this experiment are illustrated in Figure 2-5. As in Fig. 2-4, the blue line shows the optimal manipulation schedule when the market holds naive beliefs, while the red line traces manipulation when the market has rational expectations. The green line plots the manipulation function arising from the experiment we have just described. As discussed above, a comparison of the blue and red lines is not a good gauge of the impact of rational expectations on optimal manipulation because the red line is potentially contaminated by the negative externality. A comparison of the blue and green lines, on the other hand, is a better measure as the green line is drawn under the assumption that negative externalities have been killed off (or at least, substantially reduced). Fig. 2-5 then provides some evidence for the intuition that while rational expectations tend to decrease manipulation (blue above green), negative externalities do appear to increase it (red above green).

2.2.4 Effectiveness of manipulation

We now turn to investigating the effectiveness of manipulation. Since governments manipulate to increase average prices, the effectiveness of manipulation can be measured as the difference between average prices with and without manipulation. Figure 2-6 plots the conditional expected bond price, $\mathbb{E}_{y,z}[Q|\theta, a(\cdot)]$, as a function of θ for different assumptions about manipulation and market beliefs. The figure shows that not all governments benefit from manipulation. Specifically, good enough governments on average face lower interest rates and default risk, while worse types faces higher rates and default risk. Hence having access to manipulation is not universally beneficial: some government types would pay for a commitment technology that prevented them from manipulating.

Hence it must be the case that for small enough θ , manipulation causes the market to become less optimistic about the fundamentals. These governments cannot escape the combination of rational expectations and of the negative externality, and the presence of manipulation causes them to be pooled together with worse types.

For high enough θ , the opposite is true, and manipulation helps some governments to separate from worse types and pool with better ones.

Moreover, government types with the biggest incentive to manipulate end up being losers in equilibrium. These types are those whose optimal manipulation choice is mostly affected by the twin presence of rational expectations and negative manipulation externalities. By Fig. 2-4, those are the “very bad types” with $\theta < \underline{\theta}$. Fig. 2-6 then shows that these governments are also those who experience the largest interest rate increases. Also note that some of the losers choose a strictly positive manipulation action, which suggests that for those types the impact of the negative manipulation externality from better types is large enough to partially offset the impact of rational expectations.

To gain further insight into what may be driving these differences, we apply the same “decomposition” of manipulation incentives into rational expectations and externality effects we performed in Section 3.3 to two different sets of values of θ , one corresponding to “losers” and one to “winners” from access to manipulation. Specifically, we consider the intervals $\theta \in [-1, 0.5]$ (losers) and $\theta \in [2, 2.5]$ (winners). The decomposition is presented in Figure 2-7. The message of this analysis is twofold. First, the rational expectations effect has more bite when it comes to losers, for whom its presence tends to decrease optimal manipulation more relative to the benchmark with naive beliefs. Second, the presence of the manipulation externality pushes losers to manipulate *less* and winners to manipulate more, which suggests that losers do not compensate for the negative externality in equilibrium, they simply endure it. This may be due to the fact that in equilibrium, losers face a relatively larger mass of better types which do manipulate, rather than worse types. It is plausible that in these circumstances, bad types would have to choose a very large manipulation action to make it harder for the market to separate them from the better types. This may just be too costly. In addition, bad types face fewer worse types that do manipulate, so it may be harder for the market to pool the bad types in $[-1, -.5]$ with worse types than it is for them to pool the good types in $[2, 2.5]$ with worse types. Hence the extent of the externality coming from worse types may be smaller. We conclude that winners are better off with manipulation both because they are less affected by negative externality and because they compensate for the negative externality by manipulating more.

2.2.5 Transparency

An important issue in the policy debate about crises is that of transparency. One interpretation of transparency is that of an improvement in the quality of informa-

tion about fundamentals, which makes it natural for it to be modelled as an increase in the precision of information (e.g. Metz (2002), Heinemann and Illing (2002)). To better understand the implications of greater transparency for manipulation incentives, equilibrium manipulation, and equilibrium interest rates, we now turn to some comparative statics with respect to α_y .

As pointed out in Morris and Shin (2004), if equilibrium uniqueness depends on the precision of information, one has to be careful about how to take limits for $\alpha_y \rightarrow +\infty$. In our benchmark model without manipulation, for instance, the sufficient condition for equilibrium uniqueness, Assumption 3, imposes a bound on the overall quality of information, $\alpha = \alpha_x + \alpha_y + \alpha_z$. Since both α_x and α_z are bounded below by zero, α_y cannot exceed $[\kappa\beta(-1 + 1/\eta)^2/\phi(0)]^2$. Hence, given that the benchmark without manipulation serves as the gauge for the impact of manipulation on the bond price, all of our numerical examples (see Fig. 2-8 and Fig. 2-9) are computed for values of α_x , α_y and α_z consistent with these bounds. Nevertheless, by Lemma 2 and Proposition 2, our sufficient condition for the model where the government has access to the manipulation technology does not depend on the precision information, so we can allow α_y to growth without bound and assess the implications for manipulation incentives and equilibrium manipulation, if not for prices relatively to the no manipulation benchmark.

Proposition 3 (Transparency). *For α_y large enough, there are no benefits from manipulation and $a(\theta) = 0$ for all $\theta \in \mathbb{R}$.*

Proposition 3 implies that greater transparency reduces the incentives to manipulate. As the quality of public information about fundamentals improve, governments actually cease to manipulate altogether because the effectiveness of manipulation at making higher values of the exogenous public signal more likely becomes infinitesimal. To see why this is the case, consider the following simple example. Let $f(y)$ be an increasing function such that $f' > 0$, and y a Gaussian random variable with mean μ and precision α . Define $s \equiv \sqrt{\alpha}(y - \mu)$. Now, increasing μ increases the expectation of f conditional on μ , $\mathbb{E}_y[f(y)|\mu]$, since $d\mathbb{E}_y[f(y)|\mu]/d\mu = \int_{-\infty}^{+\infty} f'(\mu + u/\sqrt{\alpha})\phi(s)ds > 0$. We can think of this derivative as representing the marginal benefit from manipulation. Next, observe that for $\alpha \rightarrow +\infty$, this marginal benefit becomes negligible, as $d\mathbb{E}_y[f(y)|\mu]/d\mu \rightarrow 0$. Hence for sufficiently large α_y , manipulation becomes useless. Intuitively, as the precision of α_y grows arbitrarily large, the private sector no longer faces any fundamentals uncertainty and rational expectations can perfectly undo the effects of any manipulation action. Figure 2-8 shows these forces at work. The figure illustrates how manipulation has a smaller impact on the bond price as α_y increases.

Away from the limit, it is harder to characterise the impact of changes in α_y on manipulation incentives. The public information precision affects government incentives through two channels. First, by changing the price function $Q(y, z)$ for all (y, z) (price channel), and second, by changing the distribution of y for given Q (distribution channel). To the extent that higher α_y reduces fundamentals uncertainty, the relative strength of the rational expectations and negative externality effect ought to be affected, and the price function will reflect this new balance. In addition, higher α_y means higher values of y are now less likely to occur, which tends to decrease the expected price level for any choice of the manipulation action and any price function $Q(y, z)$. This hurts the government and increases the marginal benefit from manipulation, so the optimal manipulation action tends to increase. On the other hand, lower realisations of y are also less likely to come by. This tends to increase the average price level instead, thereby benefiting the government and decreasing the marginal benefit from manipulation. This second effect works to decrease the optimal manipulation.

Figure 2-9 suggests that the negative externality effect on the incentives to manipulate gets stronger as α_y gets larger, as the difference between manipulation with naive and with rational beliefs gets smaller. For α_y large enough, the negative externality is sufficiently strong to more than compensate for rational expectations, and some governments end up manipulating *more* when the market holds rational beliefs than when it holds naive beliefs. In addition, for low values of α_y , increasing the precision causes manipulation to increase uniformly, but as α_y gets larger bad governments and good governments manipulate less than before. This suggests that the price channel dominates for lower values of the precision, but the distribution channel becomes stronger for some types as α_y increases.

Finally, Figure 2-8 shows that the impact of manipulation on the price decreases with α_y . Despite manipulating more, governments cannot move prices as much when there is lower fundamentals uncertainty. Intuitively, although the relative impact of rational expectations on manipulation incentives seems to decrease with α_y , the lower uncertainty the harder it should be to fool the market (as per Proposition 3), and hence the stronger the impact of rational expectations, even away from the limit.

The result that manipulation becomes ineffective as the precision of the endogenously biased signal increases is in sharp contrast with Edmond (2011). He shows that in a global game with endogenous manipulation of private information, the larger the precision of the manipulated signal, the more effective manipulation at increasing the chances of regime survival, to the point that all regime that can sur-

vive do survive. The reason for this difference is that while in Edmond’s model the government manipulates to increase the chances of survival, in our model the government’s payoff depends on the interest rate, and the distribution of the interest rate ceases to be elastic with respect to manipulation as the signal precision increases.

More broadly, our result suggests a role for monitoring and surveillance policy by independent authorities (such as the European Commission or the International Monetary Fund) in reducing the extent of government manipulation.

2.3 Benchmarks

2.3.1 Common knowledge.

Proposition 4 (Common knowledge equilibrium.). *For $\theta \leq \underline{\theta}$, there exists a unique equilibrium with default. For $\theta > \bar{\theta}$, there exists a unique equilibrium without default. For intermediate values of θ , $\theta \in (\underline{\theta}, \bar{\theta}]$, either equilibrium may arise depending on market beliefs.*

The common knowledge benchmark thus induces a partition of the fundamentals space. It is useful to introduce the following labels.

Definition 7. We label “good types” governments that never default, $\theta > \bar{\theta}$. Types that may default are labelled “bad”, $\theta \leq \underline{\theta}$. Among bad types, some default regardless of the value of the interest rate. We call these “very bad types”, $\theta \leq \underline{\theta}$. The remaining bad types may or may not default depending on the interest rate. We label these “middling types”, $\theta \in (\underline{\theta}, \bar{\theta}]$.

2.3.2 Equilibrium without manipulation.

Suppose the government does not have access to the manipulation technology. Absent manipulation, the posterior default belief can be written as

$$\Pi[\theta^*(q), x, y, z] = \Phi[\sqrt{\alpha}(\theta^*(q) - \psi\delta x - \psi(1 - \delta)z - (1 - \psi)y)] \quad (2.20)$$

with $\psi \equiv \alpha_{x,z}/\alpha$ and $\alpha \equiv \alpha_{x,z} + \alpha_y$. As a result, by (2.17) the analogue of (2.19) is now

$$\theta^*(q) + \frac{\psi\delta\gamma}{\sqrt{\alpha_x}} - \frac{1}{\sqrt{\alpha}}\Phi^{-1}[\tilde{q}(q)] = \psi z + (1 - \psi)y \quad (2.21)$$

where $\theta^*(q)$ is given by (2.13). This equation implicitly defines the price correspondence in the baseline case without manipulation. The correspondence $Q(y, z)$ may

be multi-valued given that $d\theta^*/dq < 0$, so the sign of the “default effect” is negative. In order to get around the uniqueness problem, we make the following assumption.

Assumption 3 (Price uniqueness without manipulation.). *Assume that $\sqrt{\alpha}\phi(0) < \kappa\beta \left(\frac{1-\eta}{\eta}\right)^2$.*

We have the following results.

Proposition 5 (Price function without manipulation.). *If private sector beliefs are consistent with no manipulation, then*

- (i) *the price correspondence $Q(y, z)$ only depends on y and z through the linear combination $\xi \equiv \psi z + (1 - \psi)y$, so $Q(y, z) = Q(\xi)$;*
- (ii) *the price correspondence $Q(\xi)$ is non-empty for all $\xi \in \mathbb{R}$;*
- (iii) *under Assumption 3, the price correspondence $Q(\xi)$ is single-valued and monotonically increasing in ξ , with $Q(\xi) \rightarrow \bar{q}$ as $\xi \rightarrow +\infty$ and $Q(\xi) \rightarrow \underline{q}$ as $\xi \rightarrow -\infty$.*

Proposition 5 establishes that in an equilibrium without manipulation, the fundamental θ is positively correlated with the bond price and negatively correlated with default risk. The lemma also provides a sufficient condition for aggregate bond demand to be monotonic in bond prices. Assumption 3 indeed guarantees that the default effect associated with an increase in prices - which would tend to increase demand by reducing default risk - is offset by the cost effect - which tends to decrease demand by making bonds more expensive.

2.4 Extentions

2.4.1 Sovereign debt crises

In this section, we study the possibility that interest rate crises may be triggered by news about manipulation. To that end, consider the following variant of our baseline model. Everything is as detailed in Section 2, but the government has access to the manipulation technology with probability p , where $p \in [0, 1]$. This nests two previous specifications, since $p = 1$ corresponds to the baseline model, and $p = 0$ to the benchmark without manipulation. This variant allows us to treat news about manipulation as an exogenous increase in p .⁴

⁴As an alternative modeling strategy to capture increased pessimism about manipulation, we could have assumed the private sector had a common Gaussian prior with mean $\bar{\theta}_0$ and precision α_0 . In that case, an increase in $\bar{\theta}_0$ would have had similar implications as a decrease in p .

The bond price correspondence $Q(y, z)$ is now implicitly given by

$$p\Pi[\theta^*(q), y, z, a(\cdot)] + (1 - p)\Pi[\theta^*(q), y, z] = \tilde{q}(q) \quad (2.22)$$

where $\Pi[\theta^*(q), y, z, a(\cdot)]$ denotes the posterior default risk estimated by the marginal agent when the government has access to manipulation, as given by equation (2.16). Similarly, $\Pi[\theta^*(q), y, z]$ represents the posterior default belief of the marginal agent when the government does not have access to a manipulation technology, as per equation (2.20). The following condition ensures price uniqueness for a given $p \in (0, 1)$.

Assumption 4. *Assume that $\beta\kappa \left(\frac{1-\eta}{\eta}\right)^2 < p + (1 - p)\sqrt{\alpha}\phi(0)$.*

Moreover, since the posterior default belief is a linear combination of the posterior believed in the baseline model and in the benchmark without manipulation, it is easy to establish that there are incentives to manipulate.

Corollary 3. *Under Assumption 4, the price correspondence is single-valued and increasing in both y and z .*

Note that as $p \rightarrow 1$, the price function approximates the price function in the baseline with manipulation. Vice-versa, for $p \rightarrow 0$, the price gets arbitrarily close to the to price in the variant without manipulation. This suggests that for sufficiently bad fundamentals, interest rate crises may be driven or exacerbated by news of manipulation. In Figure 2-14 we report an example where we consider an increase in p from 20% to 80%. The bottom panel traces the expected bond price as a function of the fundamentals for different assumptions about p , and it illustrates that when p increases, for bad fundamentals there is a substantial fall in the bond price. This confirms the intuition that bad news about manipulation indeed drive interest rate hikes provided the fundamentals are bad enough.

While this is a clear, testable, empirical prediction, one difficulty with taking this result to the data is mapping manipulation as defined in the model to manipulation actions actually undertaken by real world governments. There are a number of tricks governments can employ to attempt to fool the markets, ranging from accounting gimmickry, to one-off measures, to cost-flow adjustments. Koen and van den Noord (2005), for example, provide an inventory of major creative accounting and one-off measures in the EU, while more recently Weber (2012) investigates stock-flow adjustments in a large sample of countries. The type of manipulation we have in mind, however, is outright lying by governments about fiscally-relevant information. Although a rigorous empirical investigation is at present outside the scope of this

project, it is still interesting to consider one well-known example of manipulation news. On October 20th, 2009, the newly elected Greek finance minister, George Papakonstantinou, informed the council of European economics and finance ministers (Ecofin) that the Greek public deficit would be 12.5% of gross domestic product, more than thrice as large as previously forecasts in Athens.⁵ This announcement, now credited with marking the onset of the Eurozone debt crisis, was interpreted at the time as signaling deliberate manipulation by the Greek authorities, later confirmed in a European Commission special report issued on January 8th, 2010.⁶ Since it also clearly revealed bad fundamentals, our model predicts that interest rates ought to have increased. Figure 2-1 shows the yield of maturity on the Greek long term bond between July 31st, 2009, and December 31st, 2009. In addition to the date of October 20th, we have marked out October 10th, 2009. This is the date of a second Ecofin meeting when concern was first expressed about the quality of Greek fiscal information and the forementioned Commission report was ordered. The figure clearly shows a marked increase in interest rates following both meetings, after a period during which interest rates had been stable, which is consistent with the prediction of our model.

2.4.2 Manipulation technology

Inasmuch as public information works as a coordination device, manipulating public information ought to be more effective than manipulating private information, if it helps the private sector coordinate on an a better equilibrium. This intuition however does not take into account that in models with strategic complementarity and endogenous financial prices, these play both an information and a coordination role (Angeletos and Werning (2006)).

The positive correlation between interest rates and default risk in our model introduces strategic complementarity amongst agents. When agent i believes the government will default because the interest rate is high, she will only lend provided she gets a high rate, and vice-versa. Hence, the private sector faces a coordination problem. While agents do not observe price realizations, because individual bond demand functions are conditional on q , it is “as if” they had observed the price. Since higher prices correlate with lower default risk for any level of the fundamentals, they make agents more likely to participate in the market, increasing aggregate bond

⁵See, for instance, the Financial Times article about the Ecofin announcement issued on October 20th, 2009 <http://www.ft.com/cms/s/0/3e7e0e46-bd47-11de-9f6a-00144feab49a.html#axzz2VdCU5et9>.

⁶The report can be found at http://epp.eurostat.ec.europa.eu/cache/ITY_PUBLIC/COM_2010_REPORT_GREEK/EN/COM_2010_REPORT_GREEK-EN.PDF

demand. This in turn lowers the realized price, thereby decreasing default risk and increasing returns.

Moreover, the bond price aggregates private information and it is therefore informative about the fundamentals. Specifically, if price function is monotonically increasing in the fundamental, a higher price signals a better government type to the entire market. If the relative precision of the price signal is large enough for the endogenous public price signal to matter for the posterior beliefs of the private sector, a higher signal encourages participation in the financial market (i.e. lending to the government) and helps coordination on a better equilibrium. In this sense, the price works as a coordination device as well as a source of strategic complementarity.

Observe, however, that higher realizations of the exogenous public signal y have similar implications as higher prices. By signaling better fundamentals, higher realizations of y also make participation more likely, thus increasing bond demand and decreasing prices and default risk. In this sense, therefore, exogenous public information plays a similar coordinating role as prices in our model.

This suggests that applying manipulation to private rather than public information may not result in large gains in the effectiveness of manipulation, as biasing the mean of private signals x_1 upwards is equivalent to distorting the mean of the price signal z , and both z and y play a similar coordination role.

A variant with private information manipulation.

We explore these issues next by considering a variant of our baseline model where the government manipulates the mean of the uncorrelated signal $x_{i,1}$. The government distorts the mean of the private signal x_1

$$x_{1,i} = \theta + a + \varepsilon_{1,i} \quad (2.23)$$

As a result, conditional on the vector (θ, s) , the sufficient statistic $x_i = \omega x_{1,i} + (1 - \omega)x_{2,i}$ is Gaussian with mean $\theta + \omega a + (1 - \omega)s$ and precision $\alpha_x \equiv [\omega^2 \sigma_{x,1}^2 + (1 - \omega)^2 \sigma_{x,2}^2]^{-1}$. This in turn implies that bond demand is now given by

$$D(\theta, q, y, s, a) = \Phi[\sqrt{\alpha_x}(\theta + (1 - \omega)s + \omega a - x^*(y, q))] \quad (2.24)$$

so by Assumption 1 the market clearing condition becomes

$$x^*(y, q) + \frac{\gamma}{\sqrt{\alpha_x}} = \theta + \omega a + (1 - \omega)s \equiv z \quad (2.25)$$

which establishes that, given common knowledge of the functions $x^*(\cdot, \cdot)$, $B(\cdot)$ and $a(\cdot)$, observing the vector (y, q) is equivalent to observing the vector (y, z) , where

z is a Gaussian random variable with mean $\theta + (1 - \omega)a(\theta)$ and precision $\alpha_z \equiv \alpha_s/(1 - \omega)^2$. Note that since the endogenous public signal z conveyed by the price q arises from the aggregation of private information, some of which gets manipulated by the government, the government ends up manipulating the price signal, too.

By equation (2.25), then, the posterior default probability estimated by the marginal agent is now

$$\frac{\int_{-\infty}^{\theta^*(q)} \sqrt{\alpha_{x,z}} \phi \left[\sqrt{\alpha_{x,z}} (u + \omega a(u) - z + \delta \gamma / \sqrt{\alpha_x}) \right] \sqrt{\alpha_y} \phi [\sqrt{\alpha_y} (u - y)] du}{\int_{-\infty}^{+\infty} \sqrt{\alpha_{x,z}} \phi \left[\sqrt{\alpha_{x,z}} (u + \omega a(u) - z + \delta \gamma / \sqrt{\alpha_x}) \right] \sqrt{\alpha_y} \phi [\sqrt{\alpha_y} (u - y)] du} \quad (2.26)$$

where δ represents the weight given to x in an inference problem conditional on x and z , so $\delta \equiv \alpha_x / \alpha_{x,z}$ and $\alpha_{x,z} \equiv \alpha_x + \alpha_z$.

As in the case where manipulation operates on the mean of y , the price is found by solving the indifference condition of the marginal agent for q , which requires equating the left hand side of (2.26) with $\tilde{q}(q)$.

Contrast with public signal manipulation technology.

For simplicity, consider $\gamma = 0$. Fix an exogenous manipulation function $a(\theta)$. There are two reasons why we should expect differences in manipulation incentives, optimal manipulation and manipulation effectiveness when we consider each alternative manipulation technology. The first is that the beliefs of the market (by which we mean the beliefs of the marginal signal $z + \gamma / \sqrt{\alpha_x}$, which determine the bond price) are going to be affected differently, and hence the ensuing price function $Q(y, z)$ will not be the same (price channel). On the one hand, even if $\alpha_{x,z}$ and α_y were identical, the manipulation function would still enter beliefs in a “weaker” form with private information manipulation, since it is multiplied by ω . Hence we would expect that for similar values of $\alpha_{x,z}$ and α_y , the smaller ω , the smaller the difference between the price function with and without manipulation in the case where the government has access to private information manipulation rather than public information manipulation, and vice-versa. On the other hand, the relative precision of the market signal $\alpha_{z,y}$ and of the public signal α_y also ought to matter. Specifically, the larger $\alpha_y / \alpha_{x,z}$, the smaller the difference between the price function with and without manipulation in the case where the government has access to private information manipulation rather than public information manipulation. This is because the posterior belief should be less and less sensitive to the biased signal z .

The second reason to expect differences is that even if the price functions were identical under the two different technologies - for example, if $a(\theta) = 0$ for all θ - then the incentives to manipulate would still differ because with the private manipulation technology, the average value of z is less sensitive to changes in the

manipulation action a than the average value of y with the public manipulation technology (distribution channel). This is because $\mathbb{E}[z|\theta] = \theta + \omega a$, while $\mathbb{E}[y|\theta] = \theta + a$. Hence, a same-size manipulation action has the potential to increase the average price more when the government manipulates public rather than private information.

We first consider an example where the public and private signal have identical precision, so $\alpha_{x,1} = \alpha_y$. The information structure for this scenario is reported in the first row of Table 2.1 (Baseline). The results are reported in Figure 2-11. The left

	$\alpha_{x,1}$	$\alpha_{x,2}$	α_x	α_s	α_z	$\alpha_{x,z}$	α_y	ω	$1 - \delta$
Baseline	1	0.25	1.25	0.25	6.25	7.5	1	0.8	0.6667
Scenario I	0.1	0.3	0.4	0.25	0.4444	0.8444	1	0.25	0.5263
Scenario II	0.2	0.3	0.5	0.25	0.6944	1.1944	1	0.4	0.5814
Scenario III	0.3	0.3	0.6	0.25	1	1.6	1	0.5	0.6250

Table 2.1: Information structure for each scenario reported in Figure 2-12.

panel is the equivalent of Fig. 2-4 and the right panel is the equivalent of Fig. 2-6. A comparison of the results in these three figures suggests that the impact of negative externalities on manipulation is much stronger when the manipulation technology operates on the mean of the private signal x_1 rather than on the mean of the public signal y . As shown in the right panel of Fig. 2-11, when the market holds naive beliefs governments have very little incentives to manipulate, whereas in equilibrium they manipulate much more.⁷ Since they also manipulate more than when the public signal is affected (see top left panel in Fig. 2-12), it looks like the negative externality has a relatively bigger impact for private information manipulation. In spite of these substantial differences, we do not find much support for the hypothesis that manipulating the public signal may more efficient than manipulating the private signal. As shown in the top right panel of Fig. 2-12, the price impact - as measured by the reduction in the average price relative to the benchmark without manipulation - is not very different across the two specifications. Nonetheless, a similar price impact is achieved at a greater cost when the manipulation technology operates on the private rather than on the public signal, since the government manipulates more in the former case than in the latter. In this sense, it looks like private information manipulation is indeed more efficient.

⁷The manipulation function with naive beliefs and private signal manipulation appears as $a(\theta) = 0$. This is just a matter of scale, as $a(\theta) = \varepsilon$, for small ε .

We next investigate whether this result is robust to changes in the information structure, and consider three alternative scenarios which are illustrated in the bottom six panels of Fig. 2-13 and Fig. 2-12. The corresponding information structure is reported in the bottom three rows of Table 2.1 (Scenarios I to III). In all three cases, $\alpha_{x,1} < \alpha_y$, but as discussed earlier, the relevant comparison is between α_y and the vector $(\alpha_z, \alpha_{x,y})$. In Scenario I, $\alpha_{x,z} < \alpha_z < \alpha_y$. In Scenario II, $\alpha_{x,z} < \alpha_y < \alpha_z$ and in Scenario III, $\alpha_y = \alpha_{x,z} < \alpha_z$.⁸ First, Fig. 2-13 shows that the negative externality effect on manipulation is still relatively stronger when the technology operates on the mean of private information, regardless of the information structure. With the private technology, this effect gets stronger for larger $\alpha_{x,1}$, as it does for larger α_y under the assumption of public manipulation (shown earlier). While that the relative precision of private and public information matters for the optimal manipulation - which is now larger with the public technology than with the private - it does not seem to make a difference for the impact on the bond price, which tends to be similar across the two technologies. In this sense, achieving the same price impact is now costlier for the government when the manipulation distorts the mean of y rather than x_1 , so manipulating private information is more efficient.

We conclude that whether private or public information is more effective depends on both the information structure and the value of the fundamentals. The higher the relative precision of public information (i.e. $\alpha_y/\alpha_{x,1}$), the more better (worse) types stand to gain (lose) from manipulating the public signal.

As a robustness check on these results, in the Appendix we study a variant of the model where the bond price is exogenously given. In this variant, the bond price no longer works as a potentially biased source of information, and as a result, it no longer affects coordination. Hence, a model with exogenous prices may furnish a better setting to test the hypothesis that manipulating a public signal - which has “coordination potential” - ought to be more effective than manipulating a private signal which does not. In our experiments, however, we find that changing the type of manipulation technology the government has access to has minimal impact on manipulation incentives, equilibrium manipulation and the impact of manipulation on average borrowing. This suggests that the differences in incentives and equilibrium manipulation observed across the two different manipulation technologies for the case with endogenous prices may indeed be due to the coordination role of prices.

⁸We experimented with larger values of $\alpha_{x,1}$ such that $\alpha_y < \alpha_{x,z} < \alpha_z$. However, the solution algorithm had a hard time converging.

2.5 Comparison with career concerns models

The career concern models of Holmstrom (1999) and Dewatripont et al. (1999) feature a manager that “manipulates” by providing effort so as to increase her market wage, which is contingent on past performance. In this sense, the model is similar to ours. There are, however, three important differences. First, career concerns models assume symmetric information. Second, there are no public signals to help coordination. Third, private sector actions are not strategic complements. For each of the three assumptions, we next briefly investigate how manipulation incentives and optimal manipulation would be affected if they were to be introduced in career concerns model.

2.5.1 Asymmetric information about managerial talent θ

In its simplest version, the career concern model features two periods, $t \in \{1, 2\}$, and two agents. There is a manager with talent θ and a measure-1 continuum of identical firms indexed by $i \in [0, 1]$. Since all firms are identical, we shall refer to them as “the market”. The manager chooses whether or not to put in effort, $a_t \geq 0$, to increase output y_t , which is given by $y_t = \theta + a_t + \varepsilon_t$, where ε_t is a Gaussian shock with zero mean and precision α_ε . The market rewards the manager with a wage w_t , which cannot be contingent on y_t but can be contingent on y_{t-1} . The manager’s talent θ is unknown to both manager and market. However, there is a common Gaussian prior about θ with mean θ_0 and precision α_0 , so information is symmetric. In the first period, the manager receives some fixed wage w_1 . In the second period, she is paid w_2 . The market is competitive, so w_2 is set at such level as to make the expected profit of the market equal to zero, $w_2 = \mathbb{E}[y_2|y_1, a_1^*]$. Now, since $y_2 = \theta + \varepsilon_2 + a_2^*$ and $a_2^* = 0$, we have that $\mathbb{E}[y_2|y_1, a_1^*] = \mathbb{E}[\theta|y_1, a_1^*]$, where $y_1 = \theta + \varepsilon_1 + a_1^*$ and a_1^* is the equilibrium effort. Note that observing y_1 and the optimal effort a_1^* is equivalent to observing a Gaussian signal z_1 about θ with precision α_ε , $z_1 \equiv \theta + \varepsilon_1 = y_1 - a_1^*$. It follows that $w_2 = \delta\theta_0 + (1 - \delta)z_1$, where $\delta \equiv \alpha_0/(\alpha_0 + \alpha_\varepsilon)$. In the first period, the manager solves

$$\max_{a_1 \geq 0} \{w_1 + \beta \mathbb{E}_\theta[w_2] - C(a_1)\}$$

where β denotes the manager’s discount factor and $C(a)$ her effort cost. This is equivalent to

$$\max_{a_1} \{w_1 + \beta \mathbb{E}_\theta[\delta \bar{\theta}_0 + (1 - \delta)(\theta + \varepsilon_1 + a_1 - a_1^*)] - C(a_1) + \mu a_1\}$$

which results in the optimality conditions

$$\begin{aligned}\beta(1 - \delta) - C'(a_1) &= -\mu \\ \mu &\geq 0 \\ \mu \cdot a_1 &= 0\end{aligned}$$

The optimality conditions show that in this model, the incentives to manipulate depend only on the uncertainty about θ , $(\alpha_0, \alpha_\varepsilon)$. Specifically, since the weight of the prior in the market inference, δ , is decreasing in $\alpha_\varepsilon/\alpha_0$, the marginal benefit of manipulation is increasing in α_ε

$$\frac{\partial \delta}{\partial \alpha_\varepsilon} = \frac{\alpha_0}{(\alpha_0 + \alpha_\varepsilon)^2} > 0$$

Consider then an interior solution such that $\beta(1 - \delta) = C'(a_1)$. For given α_0 , the optimal effort increases in α_ε

$$\frac{\partial a_1}{\partial \alpha_\varepsilon} = \frac{\alpha_0}{(\alpha_0 + \alpha_\varepsilon)^2} \frac{1}{C''(a_1)} > 0$$

since the cost function $C(a_1)$ is convex. Hence not only do the incentives to manipulate increase with α_ε , but the optimal manipulation action also increases. In other words, the greater the noise in the performance signal y_1 , the smaller the impact of rational expectations on the incentives to manipulate, and hence the larger the manipulation action.

This implication is not robust to the presence of asymmetric information. Suppose the manager observed its type. Then the manipulation action in the second period would be $a_2^*(\theta) = 0$ for all θ . In the first period, we would have that $a_1^* = a_1^*(\theta)$, and as a result

$$w_2(y_1) = \frac{\int_{-\infty}^{+\infty} u \phi[\sqrt{\alpha_0}(u - \bar{\theta}_0)] \phi[\sqrt{\alpha_\varepsilon}(y_1 - u - a_1^*(u))] du}{\int_{-\infty}^{+\infty} \phi[\sqrt{\alpha_0}(u - \bar{\theta}_0)] \phi[\sqrt{\alpha_\varepsilon}(y_1 - u - a_1^*(u))] du}$$

which can be shown to be increasing in y_1 . The manager maximises

$$w_1 + \beta \mathbb{E}_{y_1} [w_2(y_1) | \theta, a_1] - C(a_1)$$

where $y_1 | \theta, a_1$ is a Gaussian with mean $\theta + a_1$ and precision α_ε . Then since $w_2(y_1)$ is an increasing function of y_1 , the are benefits from manipulation. Moreover, since w_2 takes into account the entire function $a_1^*(\theta')$, a type- θ manager internalises the

optimal action of each $\theta' \neq \theta$. In this sense, the incentives to manipulate for θ are affected by “externalities” from all other types. We can re-write the manager’s objective as

$$w_1 + \beta \mathbb{E}_s [w_2(\theta + a_1 + s/\sqrt{\alpha_\varepsilon})] - C(a_1)$$

where s is a standard normal Gaussian random variable. For large enough α_ε , there are no benefits from manipulation. To see this, consider the optimality condition

$$\begin{aligned} \beta \mathbb{E}_s [w'_2(\theta + a_1 + s/\sqrt{\alpha_\varepsilon})] - C'(a_1) &= -\mu \\ \mu &\geq 0 \\ \mu \cdot a_1 &= 0 \end{aligned}$$

and observe that the marginal benefit from manipulation decreases in α_ε , as in our model. The intuition for this result is that as α_ε grows arbitrarily large, the manager can no longer fool the market, who can basically infer the value of θ from z_1 . Since rational expectations completely undo the manipulation action, it does not pay to manipulate. The same intuition underpins Proposition 3 in this paper.

2.5.2 Coordination role of financial prices

In the career concerns model there is no financial market, hence no asset prices that can help firms coordinate on different equilibria. To investigate the impact of such mechanisms on the incentives to manipulate and on optimal manipulation in the career concerns model, we introduce a financial market for a risky asset with dividend θ and price p . The financial market operates in the first period only, and it opens and closes before the labour market. Firms participate in the financial market, the manager does not. Firms are risk averse with CARA preferences $u(x) = -\exp\{-\gamma x\}$. Suppose that each firm observes a public signal $\omega = \theta + \varepsilon_\omega$, where ε_ω is Gaussian with mean zero and precision α_ω . In this setting, asset demand is given by $(\mathbb{E}[\theta|\omega] - p)/(\gamma \text{VAR}[\theta|\omega])$, which is an increasing function of the exogenous public signal ω , since $\text{VAR}[\theta|\omega] = \alpha_0 + \alpha_\omega$ and $\mathbb{E}[\theta|\omega] = \kappa \bar{\theta}_0 + (1 - \kappa)\omega$, with $\kappa \equiv \alpha_0/(\alpha_0 + \alpha_\omega)$. Market clearing then implies that

$$p = \kappa \bar{\theta}_0 + (1 - \kappa)\omega - \frac{\gamma S}{\alpha_0 + \alpha_\omega}$$

where S denotes the asset supply. Since p is an increasing function of ω , it follows that the public signal helps the market coordinate on an equilibrium such that the price is higher or lower than in equilibrium where no exogenous public information

is observed.

As for the labour market, the wage now depends on both the performance signal y_1 - which is endogenously biased - and the exogenous public signal ω , $w_2 = w_2(y_1, \omega)$. Again, perfect competition amongst firms implied that $w_2 = \mathbb{E}[\theta|y_1, a_1^*, \omega] = \mathbb{E}[\theta|z_1, \omega] = \delta_0 \bar{\theta}_0 + \delta_z z_1 + \delta_\omega \omega$, where $\delta_0 \equiv \alpha_0 / (\alpha_0 + \alpha_\varepsilon + \alpha_\omega)$, $\delta_z \equiv \alpha_\varepsilon / (\alpha_0 + \alpha_\varepsilon + \alpha_\omega)$ and $\delta_\omega \equiv \alpha_\omega / (\alpha_0 + \alpha_\varepsilon + \alpha_\omega)$. We assume the manager observes ω , too. In the first period, the manager solves

$$\max_{a_1 \geq 0} \{w_1 + \beta \mathbb{E}[\delta_0 \bar{\theta}_0 + \delta_z (\theta + \varepsilon_1 + a_1 - a_1^*) + \delta_\omega \omega | \omega] - C(a_1)\}$$

resulting in the optimality conditions

$$\begin{aligned} \beta \delta_z - C'(a_1) &= -\mu \\ \mu &\geq 0 \\ \mu \cdot a_1 &= 0 \end{aligned}$$

Note that since $\delta_z < 1 - \delta$, the marginal benefit of manipulation is smaller in the presence of a coordination device, which means interior solutions are also smaller. The manager does not work as hard when the inference problem of the market benefits from additional information. We find a similar mechanism at work when we compare our baseline model to a version with exogenous prices to investigate the impact of financial development on manipulation incentives and equilibrium manipulation. In the variant with exogenous prices, the rational expectations effect on manipulation incentives is relatively weaker.

In addition, the marginal benefit may be more or less elastic with respect to α_ε compared to the baseline without coordination. To see this, recall the definition of δ_z and consider

$$\frac{\partial \delta_z}{\partial \alpha_\varepsilon} = \frac{\alpha_0 + \alpha_\omega}{(\alpha_0 + \alpha_\varepsilon + \alpha_\omega)^2} \quad \text{and} \quad \frac{\partial(1 - \delta)}{\partial \alpha_\varepsilon} = \frac{\alpha_0}{(\alpha_0 + \alpha_\varepsilon)^2}$$

One then needs to distinguish three cases: (i) $\alpha_\varepsilon < \alpha_0$ (ii) $\alpha_\varepsilon > \alpha_0$ and $(\alpha_\varepsilon + \alpha_0)(\alpha_\varepsilon - \alpha_0) < \alpha_\omega$ and (iii) $\alpha_\varepsilon > \alpha_0$ and $(\alpha_\varepsilon + \alpha_0)(\alpha_\varepsilon - \alpha_0) > \alpha_\omega$. In the first two cases, introducing a coordination device decreases the sensitivity of the marginal benefit of manipulation with respect to α_ε . Hence, the manipulation action increases with α_ε , just as in the baseline without coordination. In the last case, the opposite happens. We conclude that for large enough values of α_ε , not only does the presence of coordination cause the optimal manipulation action to decrease. It also makes it decreasing in α_ε , unlike in the standard model.

2.5.3 Strategic complementarity amongst firms

In our model, the private sector actions are strategic complements. Specifically, the larger the fraction of agents who participate in the financial market, the lower the bond price and the lower default risk, so the higher the returns from holding government bonds. This marks another difference with the career concerns model. We next modify the baseline Holmstrom model to introduce strategic complementarity among firms, and show that provided the complementarity is strong enough, both the incentives to manipulate and optimal manipulation increase relative to the baseline career concerns model.

Suppose that in the second period, $t = 2$, each firm receives a shock ξ_i which causes managerial productivity to become firm-specific, so $y_{2,i} = \theta + a_2^* + \xi_i$, where ξ_i is distributed according to some c.d.f. $F_\xi(\xi)$ with mean zero. Further assume that all firms have probability $\psi(w_{2,i}, \bar{w}_2)$ of hiring the manager, where \bar{w}_2 denotes the average wage, $\bar{w}_2 \equiv \int_0^1 w_{2,i} di$, and $\psi_1 > 0$, $\psi_2 < 0$, with $\psi_{i,j} = 0$ for all $(i, j) \in \{1, 2\}^2$. Then each firm with a shock ξ solves the following problem

$$\max_{w_2} \{(\mathbb{E}[\theta|z_1] + \xi - w_2)\psi(w_2, \bar{w}_2)\}$$

taking as given the average wage \bar{w}_2 . The optimality condition for w_2 then is

$$[\delta\theta_0 + (1 - \delta)z_1 + \xi - w_2]\psi_1 = \psi$$

so the wage is now a function $w_2 = w_2(\bar{w}_2, \xi, z_1)$, where z_1 denotes the sufficient statistic for $y_1 - a_1^*$. And note that for strategic complementarity, we need $\partial w_2 / \partial \bar{w}_2 > 0$, which requires

$$\frac{\partial w_2}{\partial \bar{w}_2} = -\frac{\psi_1 \psi_2 - \psi \psi_{1,2}}{2\psi_1^2 - \psi \psi_{1,1}} > 0$$

We assume that this inequality is satisfied. To show that there are incentives to manipulate, observe that one can write

$$\frac{\partial w_2}{\partial z_1} = (1 - \delta) + \frac{\partial w_2}{\partial \bar{w}_2} \frac{d\bar{w}_2}{dz_1}$$

Now if $\frac{\partial w_2}{\partial z_1} > 0$, then $\frac{d\bar{w}_2}{dz_1} > 0$, and manipulation would pay off. Now consider the definition of \bar{w}_2

$$\bar{w}_2 \equiv \int_{\xi} w_2(\bar{w}_2, \xi, z_1) f(\xi) d\xi$$

and observe that a sufficient condition for \bar{w}_2 to be unique is that $\int \frac{\partial w_2}{\partial \bar{w}_2} f(\xi) d\xi < 1$. This is guaranteed if the strategic complementarity is not too strong, so $0 < \frac{\partial w_2}{\partial \bar{w}_2} < 1$.

Next, we have that

$$\frac{d\bar{w}_2}{dz_1} = \int \frac{\partial w_2}{\partial z_1} f(\xi) d\xi = 1 - \delta + \frac{d\bar{w}_2}{dz_1} \int \frac{\partial w_2}{\partial \bar{w}_2} f(\xi) d\xi$$

which implies

$$\frac{d\bar{w}_2}{dz_1} = \frac{1 - \delta}{1 - \int \frac{\partial w_2}{\partial \bar{w}_2} f(\xi) d\xi} > 0$$

where the inequality follows from the uniqueness condition. Since $\frac{d\bar{w}_2}{dz_1} > 0$, $\frac{\partial w_2}{\partial z_1} > 0$ and therefore there are incentives to manipulate. The presence of the strategic complementarity also implies that each firm's wage w_2 is not more elastic with respect to the manager's effort, a_1 , than in the baseline model, where $\frac{\partial w_2}{\partial z_1} = 1 - \delta$.

As for the manager, her problem is now given by

$$\max_{a_1 \geq 0} \left\{ w_1 + \beta \mathbb{E}_\theta \left[\int_\xi \psi(w_2, \bar{w}_2) w_2 f(\xi) d\xi \right] - C(a_1) \right\}$$

where $z_1 = \theta + \varepsilon_1 + a_1 - a_1^*$, w_2 satisfies the optimality condition for firms for given \bar{w}_2 and \bar{w}_2 is the average wage. The optimality conditions for this problem are then given by

$$\begin{aligned} \beta \mathbb{E}_\theta \left[\int_\xi \left(\psi_1 \frac{\partial w_2}{\partial z_1} w_2 + \psi_2 \frac{d\bar{w}_2}{dz_1} w_2 + \psi \frac{\partial w_2}{\partial z_1} \right) f(\xi) d\xi \right] - C'(a_1) &= -\mu \\ \mu &\geq 0 \\ \mu \cdot a_1 &= 0 \end{aligned}$$

Consider now the left hand side of the first order condition for an interior solution. It is bounded below by

$$\beta \mathbb{E}_\theta \left[\int_\xi \left(\psi_1 (1 - \delta) + \left(\psi_1 \frac{\partial w_2}{\partial \bar{w}_2} + \psi_2 \right) \frac{d\bar{w}_2}{dz_1} \right) w_2 f(\xi) d\xi \right] + \beta (1 - \delta)$$

As long as the strategic complementarity is strong enough - so the term $\frac{\partial w_2}{\partial \bar{w}_2} + \frac{\psi_2}{\psi_1}$ is positive - the marginal benefit from manipulation is larger than in the baseline case, where it equals $\beta(1 - \delta)$. Hence, the optimal manipulation action - not only the manipulation incentive - is going to be larger than in the baseline with no complementarity.

2.6 Conclusion

This paper argues that manipulation of public information occurs fairly frequently in different countries and can at times be in large magnitudes. It then lays out a theoretical framework where such manipulation can be an equilibrium outcome in a global games framework with asymmetric information between the government and private investors. The government aims to issue a bond to finance a project whose return is unknown to the investors. Investors have noisy private signals and observe a public signal that may have been manipulated by the government who has access to a technology allowing it to shift the mean the public signal. Even though it is costly for the government to manipulate and the private investors internalize that the government has access to such a technology, we show that manipulation occurs in equilibrium. In addition, higher transparency weakens manipulation incentives by making it easier for investors to “catch” manipulation. In an attempt to quantitatively analyze whether any “news” that reveal a high probability of manipulation has large effects, we find that such news can generate a sizable increase the interest rate faced by the government. Finally, the manipulation technology being with regards to private signals does not make a significant difference because private signals get aggregated by the price that facilitate coordination in the way that public signals do.

Our finding that some government types would be better off if they could commit to not to manipulate may have interesting policy implications. These types are the weaker governments that manipulate the most but also benefit the least from manipulation. If a supranational body were to offer access to a program through which full commitment not to manipulate could be achieved, these types would be willing to pay to participate.⁹ The IMF has in place various programs that the member countries can subscribe to, such as the Special Data Dissemination Standards, however, it is unclear whether these programs guarantee full commitment not to manipulate.

⁹Note here that we do not take into account the potential externalities from the good types who will choose not to buy the commitment technology and whether the bad types, foreseeing that the good types will opt out may also find it optimal not to participate.

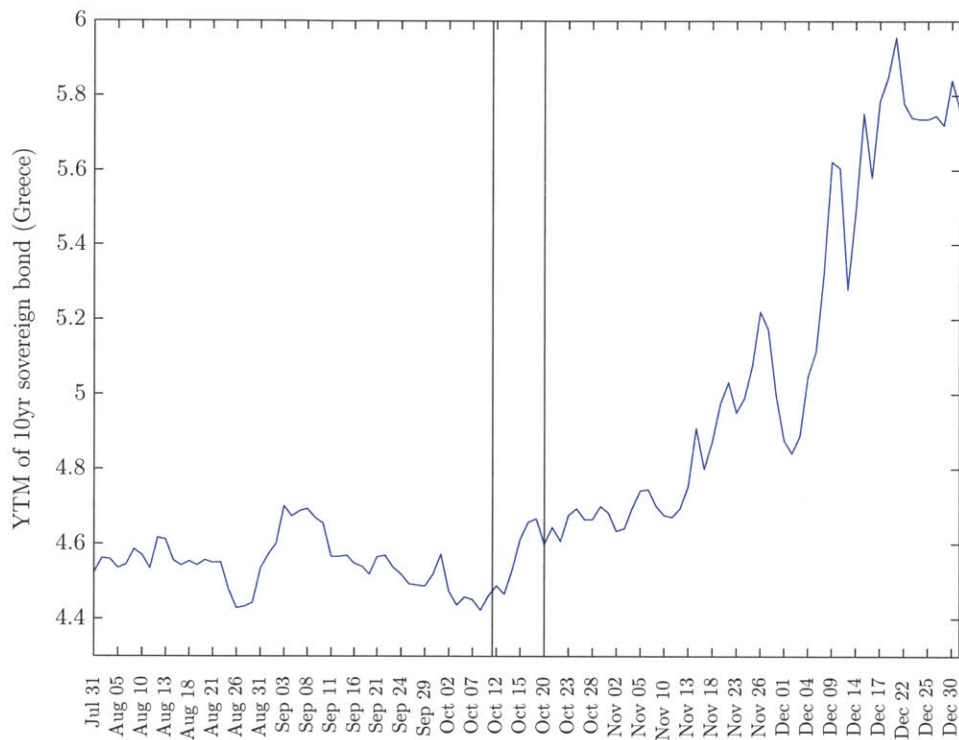


Figure 2-1: Yield to maturity of the Greek 10 year sovereign bond for the last five months of 2009 at daily frequency. The leftmost vertical line marks the date of the Ecofin meeting first expressing concern over the quality of Greek fiscal data, October 10th 2009. This is the date when the European Commission report was ordered. The rightmost vertical line marks the announcement of misreporting made by George Papacostantinou, October 20th 2009. Source: Thompson Reuters via Datastream.

TABLE 2.2: CASES OF MISREPORTING AND/OR BREACH OF I.M.F.'S ARTICLE VIII, SECTION 5

Country	Date	Misreported Series
Antigua & Barbuda	Oct 2012	central government overall deficit including grants
Angola	Nov 2011	oil revenues
Greece	May 2010	fiscal deficit
Dominican Republic	Dec 2010	overall balance of the consolidated public sector and the central administration
Ukraine	July 2010	net international reserves
Senegal	May 2010	nonconcessional external debt
Singapore	July 2009	international investment position
Senegal	Dec 2008	basic fiscal balance and the budgetary float
Tanzania	May 2008	international reserves of the Bank of Tanzania and on the stock of debt of the central government
Tajikistan	Mar 2008	net international reserves, the net domestic assets of the National Bank of Tajikistan
Dominican Republic	Jan 2008	non-accumulation of new external arrears
Cape Verde	Dec 2007	net domestic borrowing
Nigeria	June 2007	contracting/guaranteeing nonconcessional external debt by the public sector
Serbia & Montenegro	Feb 2006	ceiling on the wage bill of the public enterprises
Argentina	June 2005	non-accumulation of arrears to bilateral and multilateral creditors
Rwanda	Apr 2005	external arrears
Paraguay	Mar 2005	non-accumulation of arrears
Serbia & Montenegro	Dec 2004	net credit of the banking system to the consolidated general government
Dominica	Aug 2004	external payments arrears
Argentina	Aug 2003	information on competitive plans
Tajikistan	Feb 2002	arrears accumulated in connection with two government guarantees
Ukraine	Sept 2000	international reserves of the National Bank of Ukraine
Pakistan	Apr 2000	fiscal data

Notes: This table provides a list of cases of misreporting and/or breach of Article VIII, Section of the IMF. See text for a discussion of the definition of misreporting and the requirements of the aforementioned article. "Date" in the second column refers to the date of IMF's decision. There are a few cases not included for confidentiality reasons.

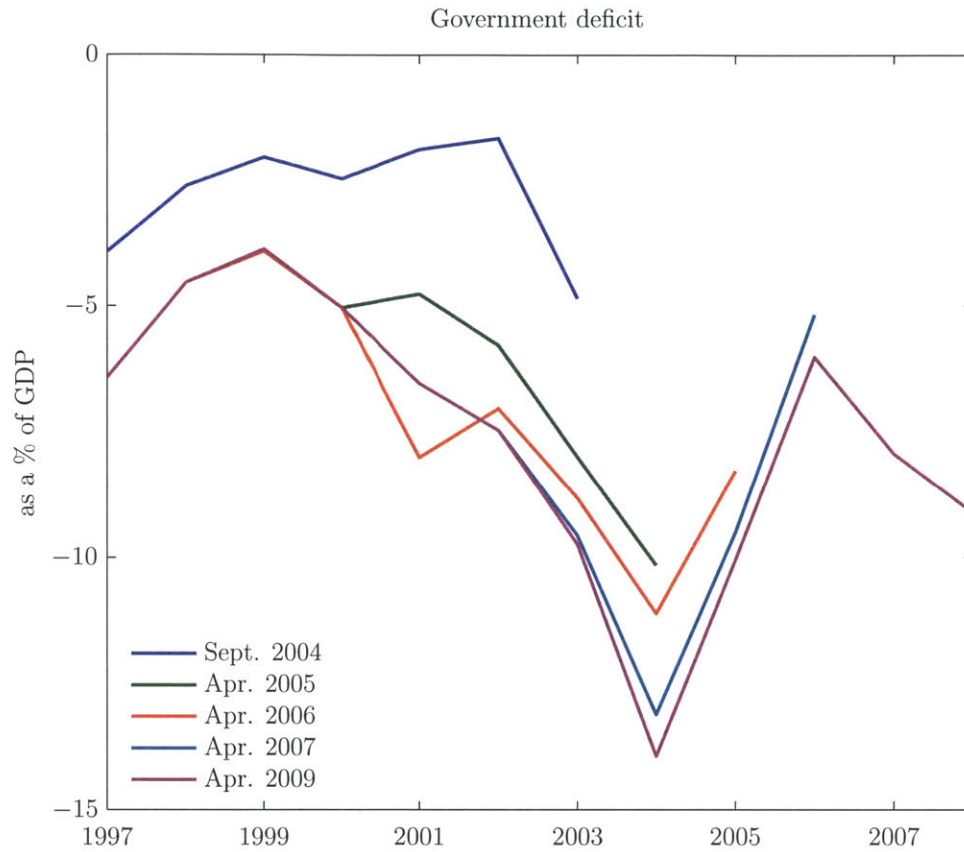


Figure 2-2: Greek deficit as a share of GDP as reported in the International Monetary Fund's World Economic Report.

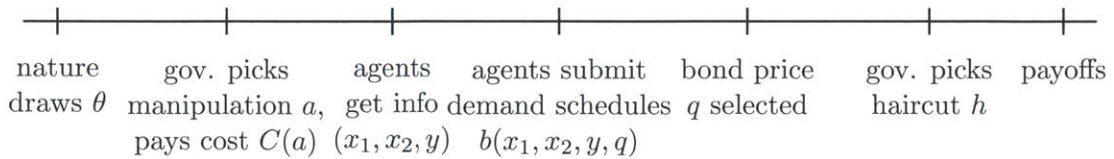


Figure 2-3: Timing summary.

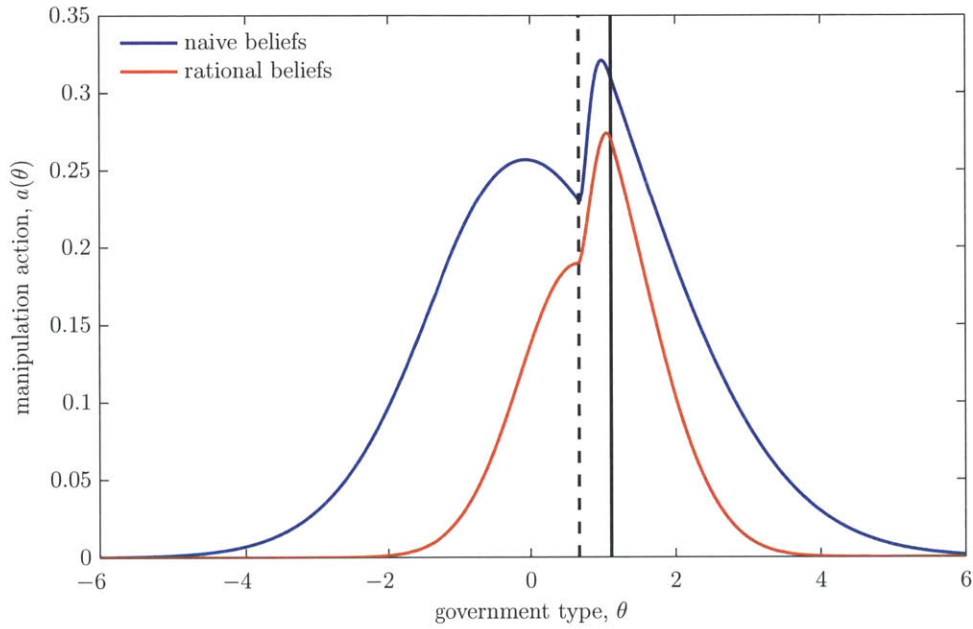


Figure 2-4: Optimal manipulation as a function of the fundamental θ . The blue line traces the manipulation when the market has “naive beliefs” so the posterior is computed under the assumption that $a(\theta) = 0$ for all $\theta \in \mathbb{R}$. The red line instead represents the manipulation when the market takes into account that the government does have access to the manipulation technology, so the beliefs take into account the optimal schedule $a(\theta)$, as given by the red line itself.

This and all remaining figures are drawn for $\gamma = 0$, $\eta = 0.4$, $\kappa = 0.6$, $\beta = 1$, $\alpha_{x,1} = \alpha_{x,2} = \alpha_s = 0.25$, $\alpha_y = 1$ and $C(a) = (c/2)a^2$, with $c = 0.2$, unless otherwise specified.

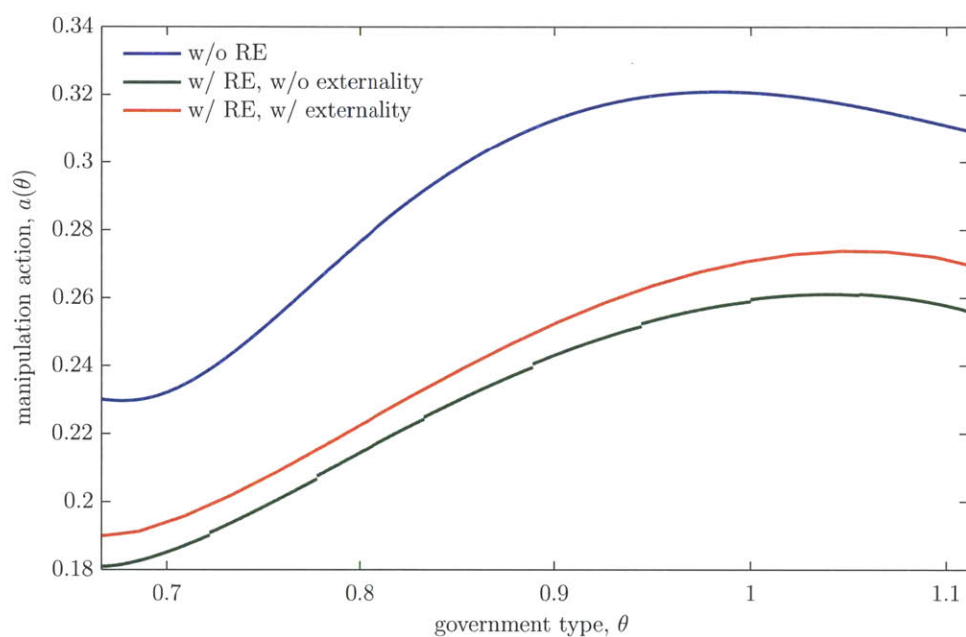


Figure 2-5: Optimal manipulation as a function of the fundamental θ for values of $\theta \in [\underline{\theta}, \bar{\theta}]$. The blue line represents optimal manipulation with naive beliefs. The green line traces the schedule $a(\theta)$ for $\theta \in [a(j), b(j)]$, where $j = 1, \dots, 8$, $a(1) = \underline{\theta}$, $b(8) = \bar{\theta}$ and $C(a, \theta) \rightarrow +\infty$ for all $\theta \notin [a(j), b(j)]$ and all j . Finally, the red line shows the optimal manipulation action in the baseline scenario where $C(a) = (c/2)a^2$.

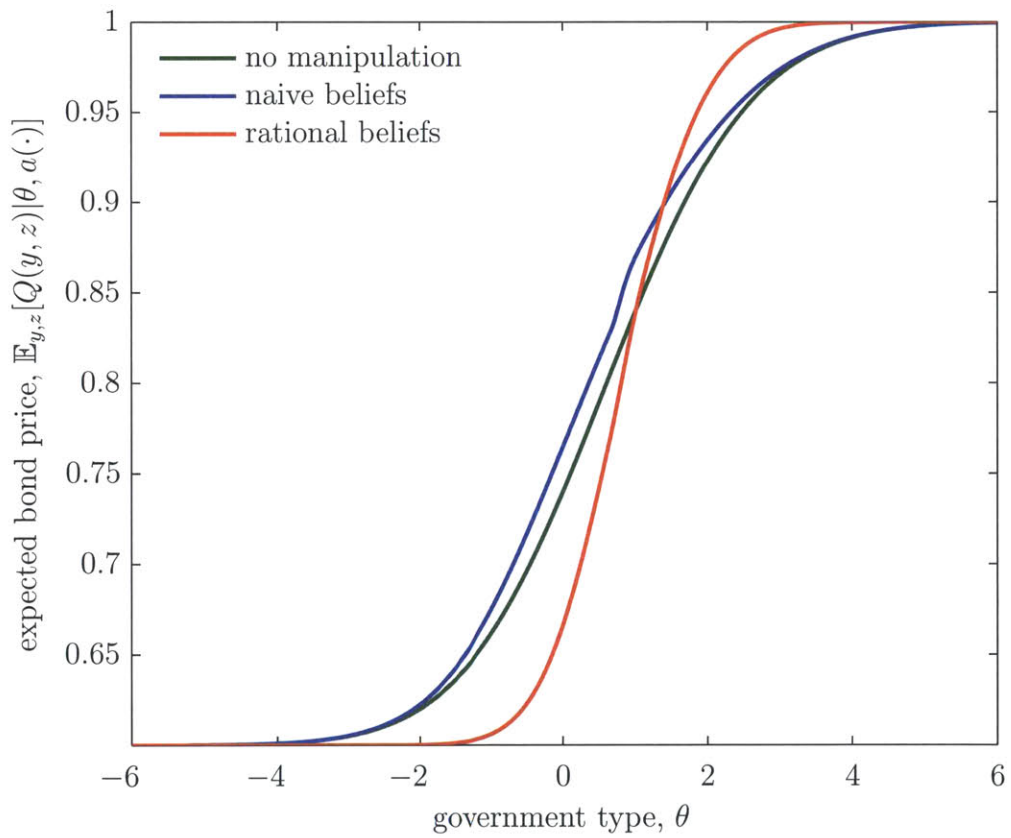


Figure 2-6: Expected bond price conditional on θ for different assumptions about the manipulation technology and market beliefs.

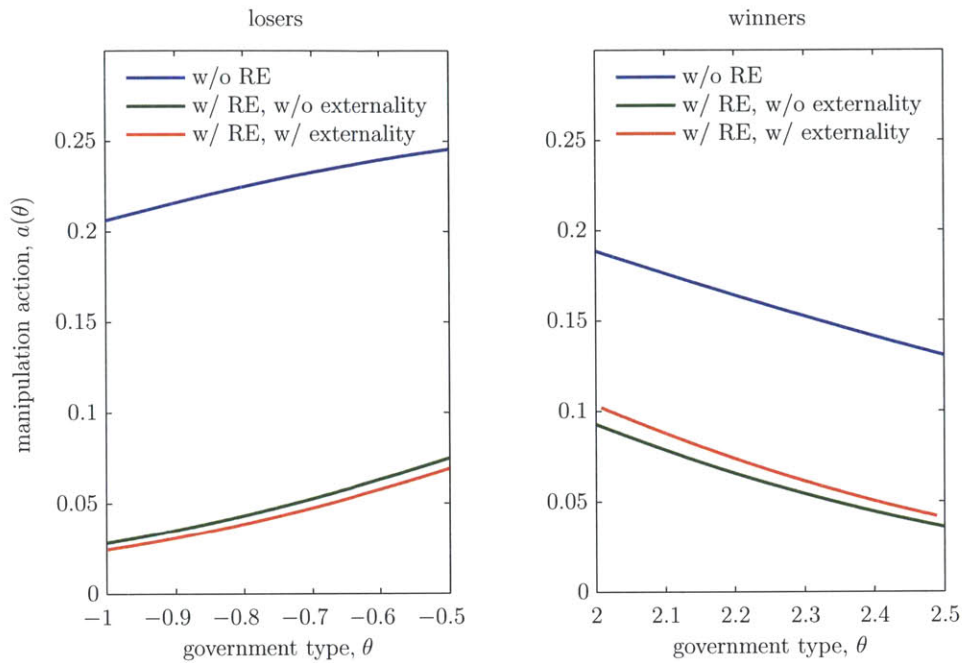


Figure 2-7: A decomposition of manipulation incentives for losers (left) and winners (right) from access to a manipulation technology.

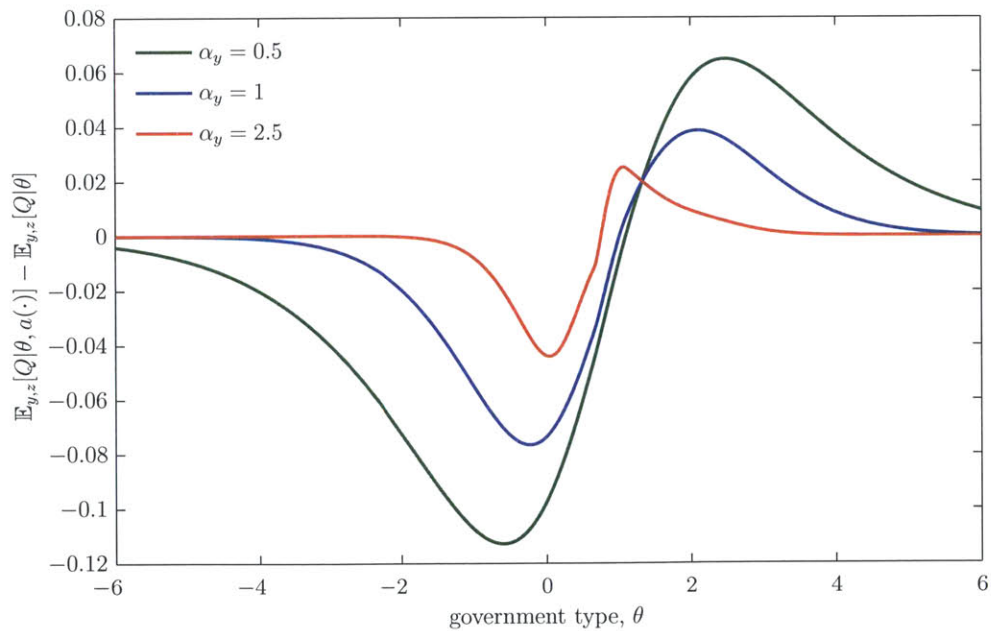


Figure 2-8: Manipulation effectiveness as a function of θ for different values of α_y .

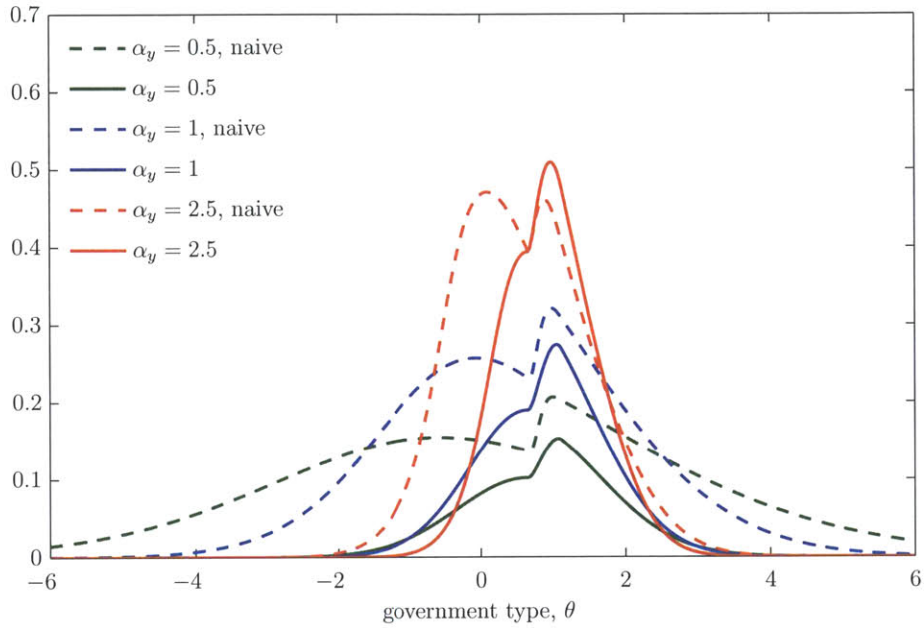


Figure 2-9: Manipulation incentives for different values of the public signal precision, α_y , and different assumptions about market beliefs concerning manipulation. The dashed lines represent the case where the market holds naive beliefs. The continuous lines embed rational expectations.

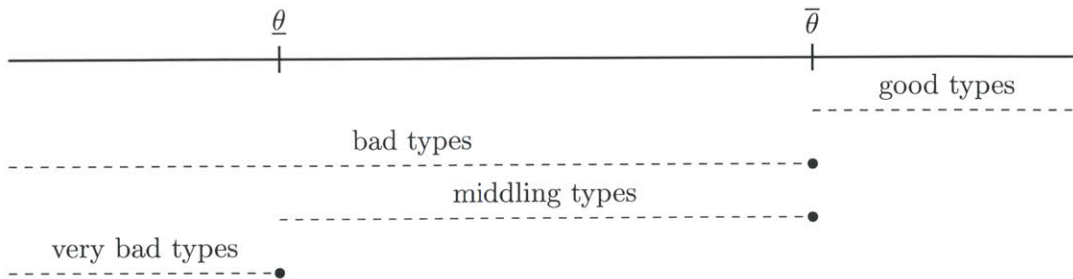


Figure 2-10: A partition of the fundamentals space under common knowledge about the fundamental θ .

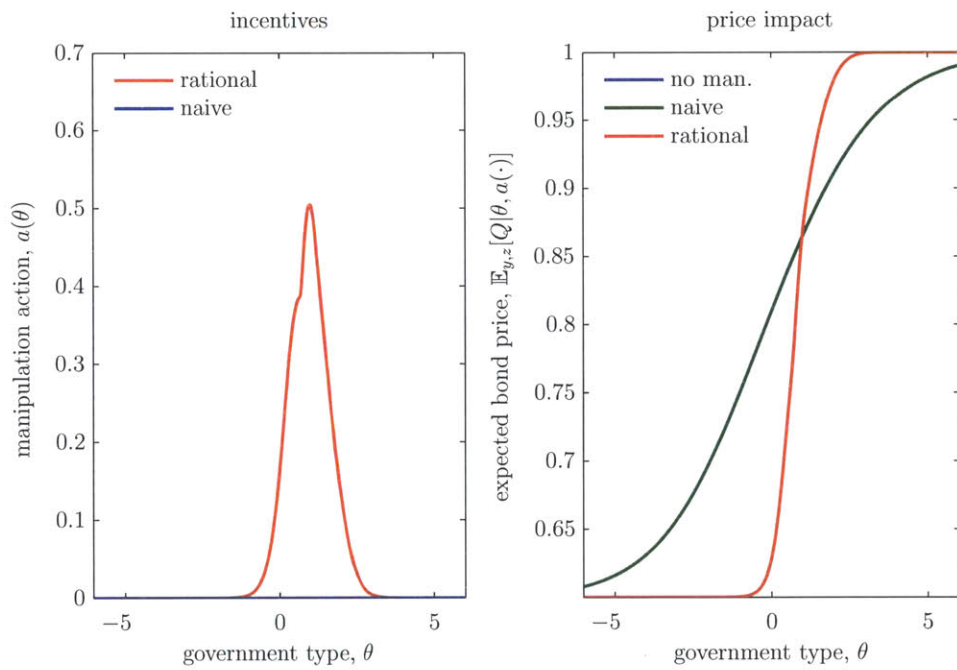


Figure 2-11: Manipulation incentives and price impact when the government has access to a manipulation technology that affects the mean of private information.

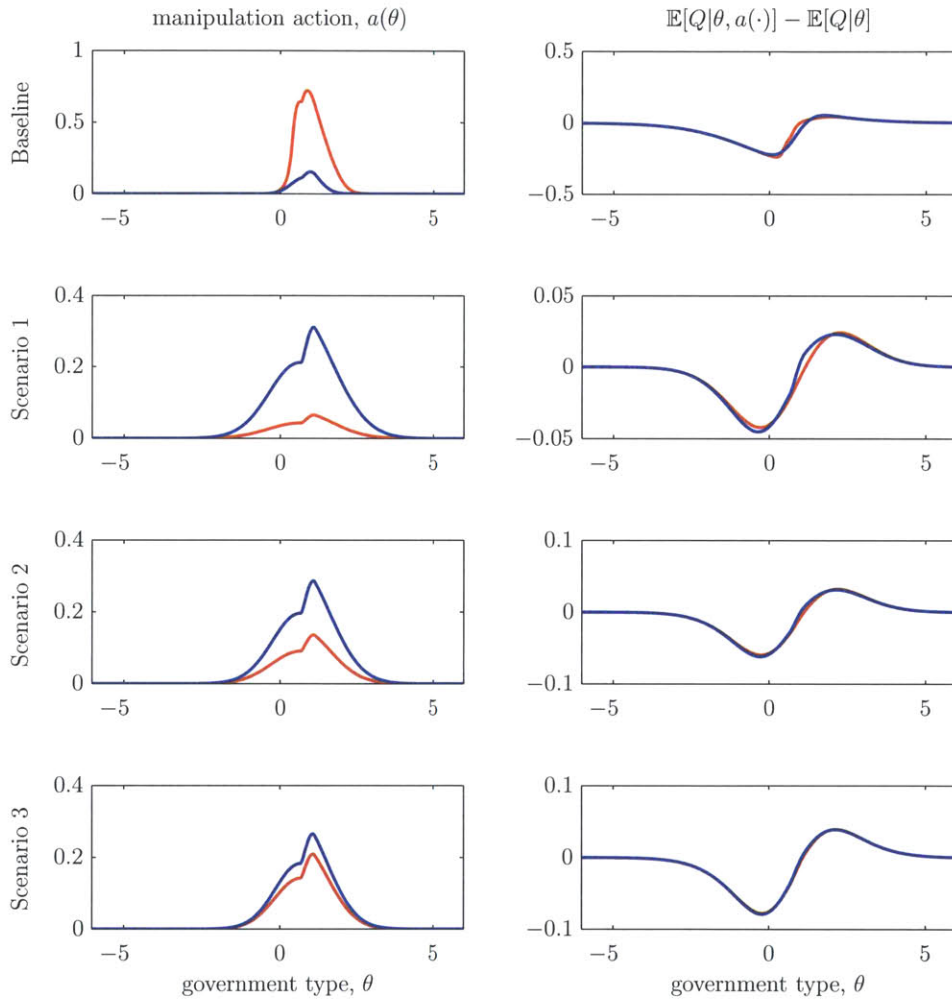


Figure 2-12: A comparison of the manipulation function (left panels) and the average price (right panels) when the government manipulates the mean of private (red lines) versus public information (blue lines). Information structure reported in Table 2.1.

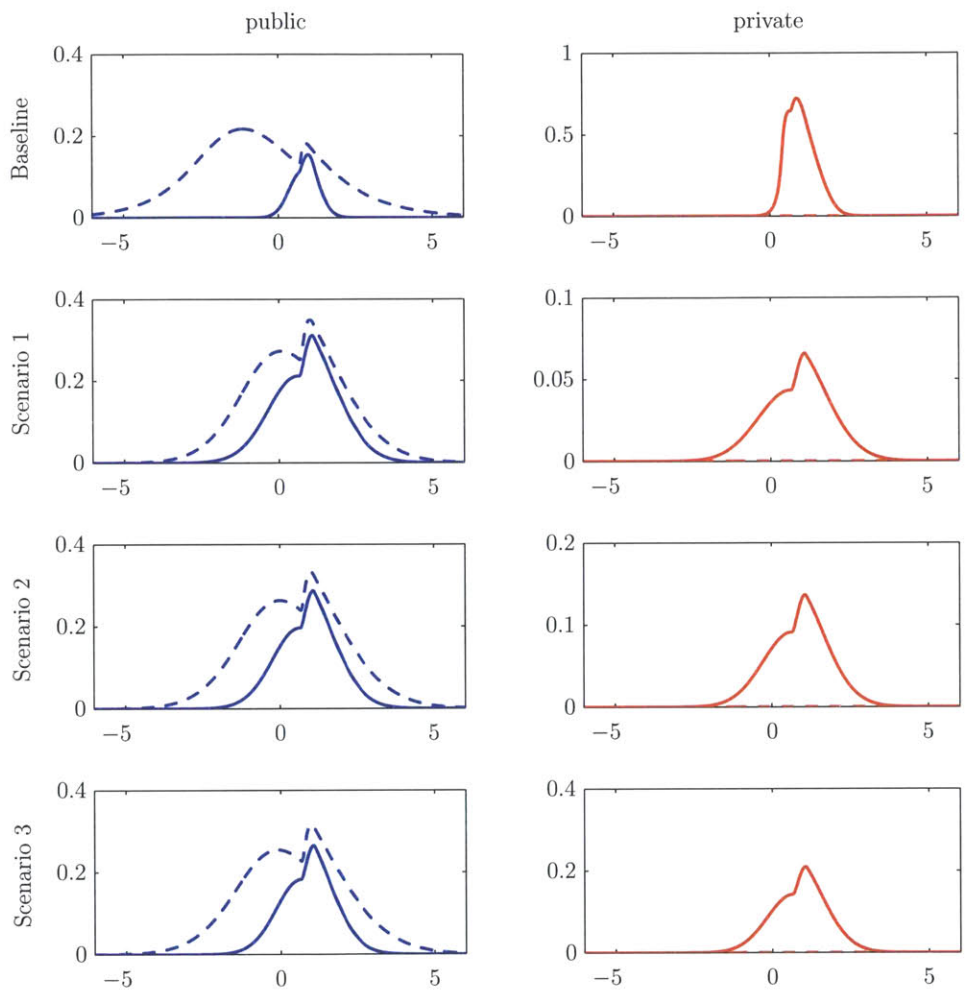


Figure 2-13: A comparison of manipulation incentives when the government manipulates the mean public (left panels) versus private information (right panels). The continuous lines represent the case where the market holds rational beliefs, the dashed lines naive beliefs. Information structure reported in Table 2.1.

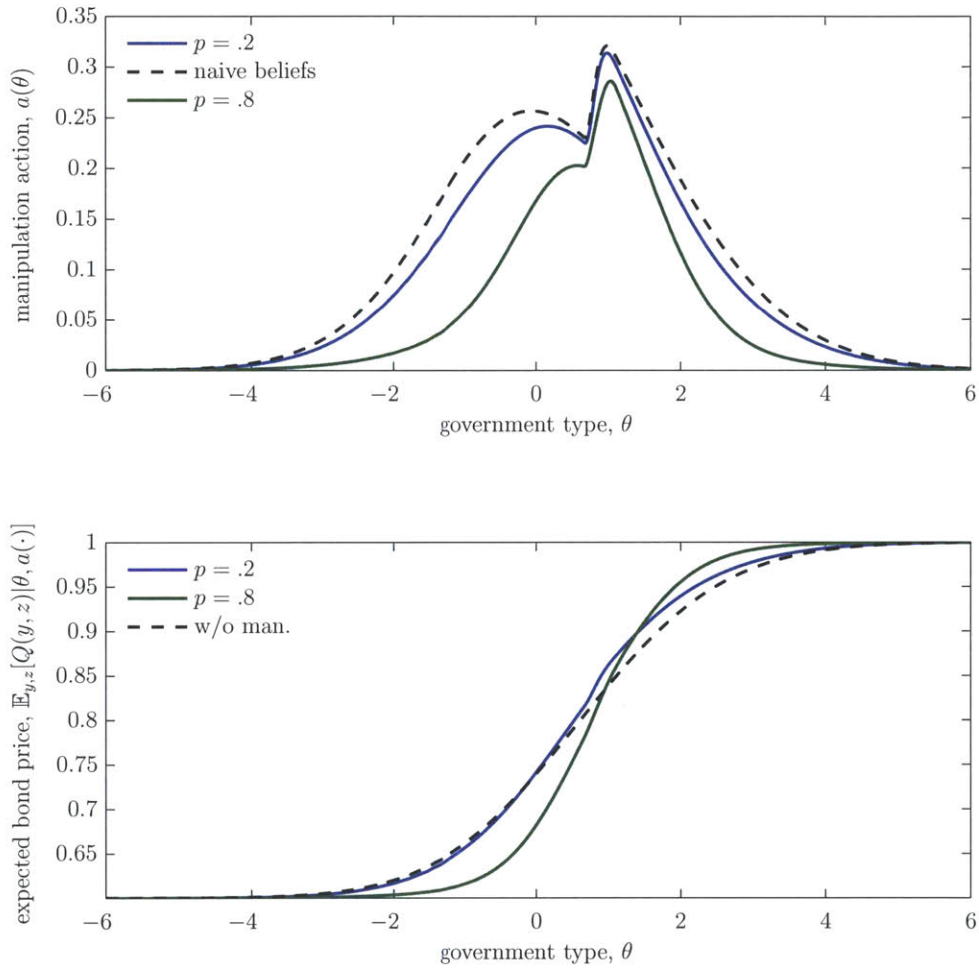


Figure 2-14: The top panel plots the optimal manipulation action $a(\theta)$ for different assumptions about the probability that the government has access to the manipulation technology p . The bottom panel plots the conditional average bond price as a function of θ for different assumptions about the probability that the government has access to the manipulation technology p .

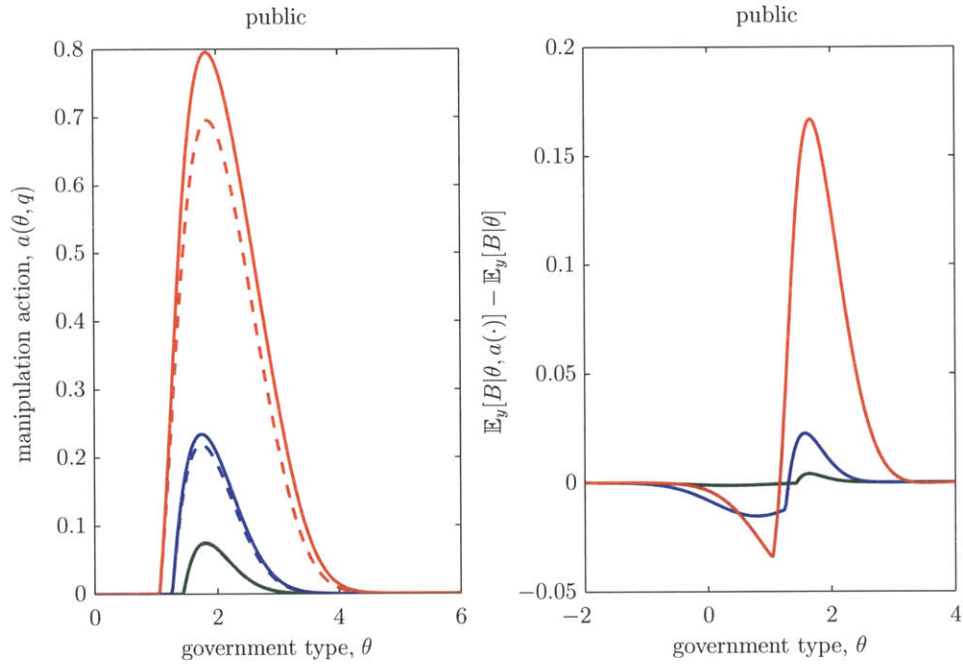


Figure 2-15: The left panel shows manipulation incentives with exogenous prices and manipulation of the public signal y . The dashed lines plot optimal manipulation when the market holds naive beliefs, while the continuous lines trace the manipulation action when the market has rational expectations. The green lines correspond to $q = 0.697$, the blue lines to $q = 0.798$ and the red lines to $q = 0.9595$. The right panel plots the difference $\mathbb{E}_y[B|\theta, a(\cdot)] - \mathbb{E}_y[B|\theta]$ for different values of the bond price. All figures for the model with exogenous prices drawn for $\alpha_{x,1} = \alpha_y = 1$.

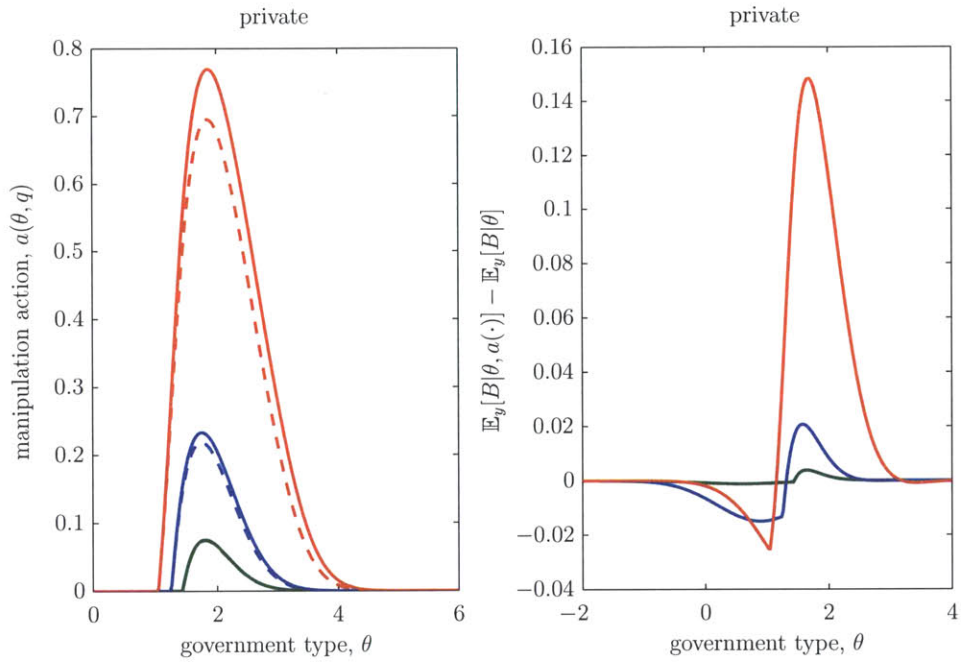


Figure 2-16: The left panel shows manipulation incentives with exogenous prices and manipulation of the private signal x_1 . The dashed lines plot optimal manipulation when the market holds naive beliefs, while the continuous lines trace the manipulation action when the market has rational expectations. The green lines correspond to $q = 0.697$, the blue lines to $q = 0.798$ and the red lines to $q = 0.9595$. The right panel plots the difference $\mathbb{E}_y[B|\theta, a(\cdot)] - \mathbb{E}_y[B|\theta]$ for different values of the bond price. All figures for the model with exogenous prices drawn for $\alpha_{x,1} = \alpha_y = 1$.

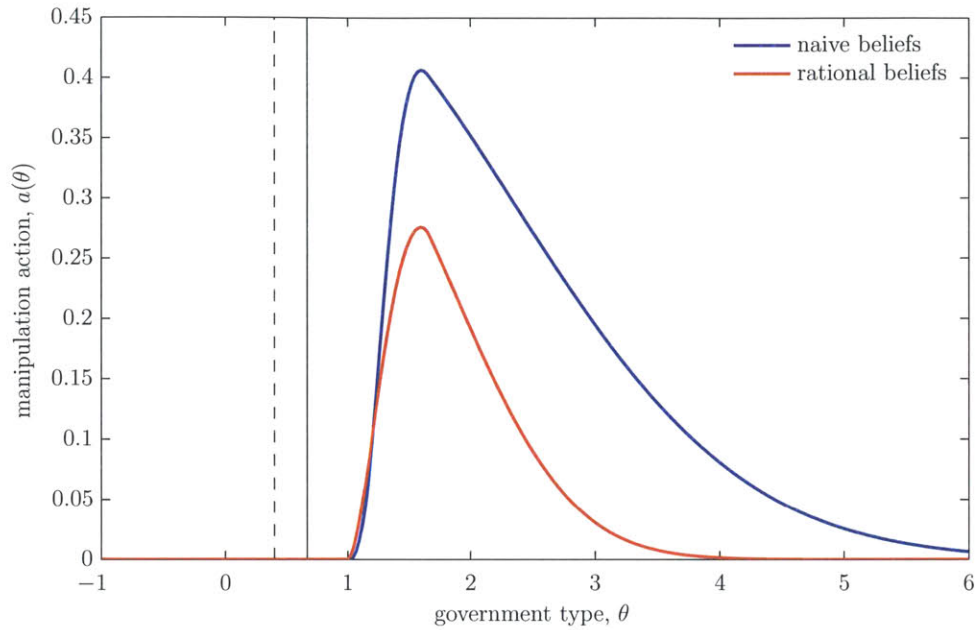


Figure 2-17: Manipulation incentives in the model where the government manipulates so as to affect default risk.

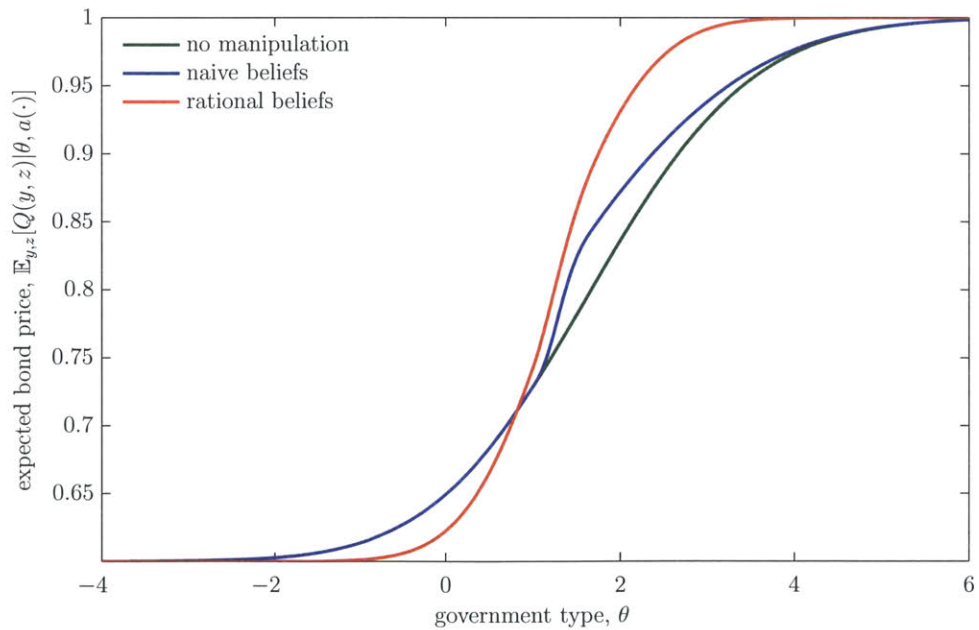


Figure 2-18: Average price in the model where the government manipulates so as to affect default risk.

2.7 Appendices

2.7.1 Proofs and omitted derivations

Common knowledge.

Proof of Proposition 4. Let $\underline{\theta} \equiv \theta^*(\bar{q})$ and $\bar{\theta} \equiv \theta^*(\underline{q})$. Consider $\theta < \underline{\theta}$. Conjecture there exists an equilibrium with default. Then it must be the case that $q = \underline{q}$ and that $\theta \leq \theta^*(\underline{q})$. Since the threshold function $\theta^*(q)$ is decreasing in q , this condition is satisfied, because $\theta < \underline{\theta} \equiv \theta^*(\bar{q}) < \theta^*(\underline{q})$. This verifies the conjecture. Now conjecture instead that there exists an equilibrium without default. In such an equilibrium, $q = \bar{q}$ and $\theta > \theta^*(\bar{q})$ which is a contradiction since we assumed $\theta < \underline{\theta} = \theta^*(\bar{q})$.

The reasoning is analogous for the two remaining regions of the fundamentals space. \square

Equilibrium without manipulation.

Proof of Proposition 5. In an equilibrium without manipulation, the posterior beliefs of agents are given by

$$\Pi[\theta^*(q), x, y, z] = \Phi[\sqrt{\alpha}(\theta^*(q) - \psi\delta x - \psi(1 - \delta)z - (1 - \psi)y)]$$

By the equilibrium condition, moreover, we have that

$$x^*(y, q) + \frac{\gamma}{\sqrt{\alpha_x}} = z$$

so we can solve for $Q(y, z)$ using the indifference condition of the private sector which implicitly defines the price function

$$\theta^*(q) + \frac{\psi\delta\gamma}{\sqrt{\alpha_x}} - \frac{1}{\sqrt{\alpha}}\Phi^{-1}[\tilde{q}(q)] = \psi z + (1 - \psi)y \equiv \xi \quad (2.27)$$

Note that the price correspondence depends on the vector (y, z) only through the linear combination $\xi \equiv \psi z + (1 - \psi)y$, so we can write $Q(y, z) \equiv Q(\xi)$. Conditional on θ and on the manipulation action a , the variable ξ has a Gaussian distribution with mean $\theta + (1 - \psi)a$ and precision $\alpha_\xi \equiv (\psi^2\sigma_z^2 + (1 - \psi)^2\sigma_y^2)^{-1}$.

Consider the left hand side of equation (2.27) as a function of q

$$G : (\underline{q}, \bar{q}) \rightarrow \mathbb{R}$$

$$q \mapsto \theta^*(q) + \frac{\psi\delta\gamma}{\sqrt{\alpha_x}} - \frac{1}{\sqrt{\alpha}}\Phi^{-1}[\tilde{q}(q)]$$

Observe that since $\gamma_q \geq 0$ and $d\tilde{q}/dq < 0$, $G(q) \rightarrow +\infty$ as $q \rightarrow \bar{q}$ and $G(q) \rightarrow -\infty$ as $q \rightarrow \underline{q}$. As a result, the price correspondence is non-empty for all $\xi \in \mathbb{R}$. Moreover, a sufficient condition for the price correspondence to be single-valued is that $dG/dq > 0$ for all $q \in (\underline{q}, \bar{q})$. This derivative is given by

$$\frac{dG}{dq} = -\frac{\eta}{\kappa q^2} + \frac{1}{\eta\beta} \frac{1}{\sqrt{\alpha}} \frac{1}{\phi(\Phi^{-1}[\tilde{q}(q)])}$$

Note that while the first term of this expression is negative, the second is positive. Furthermore, the first term is bounded above by while the second term is bounded below. As a result, a sufficient condition for the price correspondence to be single-valued is that

$$\frac{1}{\eta\beta} \frac{1}{\sqrt{\alpha}} \frac{1}{\phi(0)} > \frac{\eta}{\kappa q^2}$$

which is equivalent to Assumption 3. In addition, the uniqueness condition guarantees that the price function is monotonically increasing in ξ

$$\frac{dQ}{d\xi} = \frac{1}{\frac{d}{dq}\theta^*(q) + \frac{1}{\eta\beta} \frac{1}{\sqrt{\alpha}} \frac{1}{\phi(\Phi^{-1}[\tilde{q}(q)])}} > 0 \quad (2.28)$$

since the denominator is positive. Finally, we have that $Q(\xi) \rightarrow \bar{q}$ as $\xi \rightarrow +\infty$ and $Q(\xi) \rightarrow \underline{q}$ as $\xi \rightarrow -\infty$. \square

Equilibrium with public info manipulation

The proof of Proposition 1 is by contradiction. To that end, let us first establish an intermediary result.

Lemma 3 (Manipulation Benefits). *When the market believes $a(\theta) = 0$ for all $\theta \in \mathbb{R}$ (“naive beliefs”), there are benefits from manipulation.*

Proof of Lemma 3. Suppose that there exists an equilibrium without manipulation, so the price function is given by (2.27). Consider now the objective of a type- θ government

$$\max_{a \geq 0} \{\mathbb{E}_\xi [u_G(\theta, Q(\xi)) | \theta, a] - C(a)\}$$

where the expectation is taken with respect to the distribution of ξ conditional on θ and a . Further note that

$$u_G(\theta, q) \equiv g(\theta, q)B$$

Here, the term $g(\theta, q)$ represents the return to the government per unit collected

$$g(\theta, q) \equiv (1 - k)\theta - \frac{1 - h}{q}$$

where $k(h) = \kappa \mathbb{I}\{h > 0\}$ and $h(\theta, q) = \eta \mathbb{I}\{\theta \leq \eta/(\kappa q)\}$. The function $g(\theta, q)$ is increasing in q , and so is the function $u_G(\theta, q)$.¹⁰

Use the change of variable $\zeta = \sqrt{\alpha_\xi}(y - \theta - (1 - \psi)a)$ so that

$$\begin{aligned} \mathbb{E}_\xi\{u_G(\theta, Q(\xi))|\theta, a\} &= \int_{-\infty}^{+\infty} u_G(\theta, Q(\xi))\sqrt{\alpha_\xi}\phi[\sqrt{\alpha_\xi}(\xi - \theta - (1 - \psi)a)]d\xi \\ &= \int_{-\infty}^{+\infty} u_G[\theta, Q(\theta + (1 - \psi)a + \zeta/\sqrt{\alpha_\xi})]\phi(\zeta)d\zeta \end{aligned}$$

Note that since the function $g(\theta, q)$ is increasing in q and $dQ/d\xi > 0$ (as per equation (2.28)), the function $\partial u_G(\theta, a, \zeta)$ is increasing in a . As a result, manipulation tends to increase the expected utility of the government. Also observe that the key determinant of this result is the monotonicity of the price function with respect to ξ , which requires that (1) the posterior default belief of the market be decreasing in (y, z) and that (2) the posterior be sufficiently inelastic with respect to the bond price q . \square

Proof of Proposition 1. Suppose there exists an equilibrium such that $a(\theta) = 0$ for all θ . Fix $\theta > \bar{\theta}$. Let $Q(\theta, a, \zeta) \equiv Q^2(\theta + (1 - \psi)a + \zeta/\sqrt{\alpha_\xi})$. In light of the above, the government problem can be written as

$$\max_{a \geq 0} \left\{ \mathbb{E}_\zeta \left[\left(\theta - \frac{1}{Q(\theta, a, \zeta)} \right) \right] B - C(a) \right\}$$

For $\theta > \bar{\theta}$, the function $g(\theta, q)$ is differentiable everywhere with respect to q , so the partial derivative of $\mathbb{E}_\zeta[u_G]$ with respect to the manipulation action a is well-defined. Consider the first order condition for this problem

$$(1 - \psi)\mathbb{E}_\zeta \left[\frac{Q'(\theta, a, \zeta)}{Q^2(\theta, a, \zeta)} \right] B - C'(a) \leq 0$$

¹⁰For $\theta \in (\underline{\theta}, \bar{\theta}]$, the function g is not partially differentiable with respect to q everywhere in (q, \bar{q}) , since for any θ in this interval there exists a kink at $q = \kappa\theta/\eta$.

A necessary condition for an equilibrium without manipulation to exist is that the inequality holds strictly for all $a > 0$

$$C'(a) > (1 - \psi) \mathbb{E}_\zeta \left[\frac{Q'(\theta, a, \zeta)}{Q^2(\theta, a, \zeta)} \right] B$$

Observe next that

$$\frac{Q'}{Q^2} = \frac{\eta\beta}{\frac{1}{\eta\beta} \frac{1}{\sqrt{\alpha}} \phi(\Phi^{-1}[\bar{q}(Q)]) - 1}$$

and let

$$A \equiv \inf_{q \in (\underline{q}, \bar{q})} \left\{ \frac{\eta\beta(1 - \psi)}{\frac{1}{\eta\beta} \frac{1}{\sqrt{\alpha}} \phi(\Phi^{-1}[\bar{q}(q)]) - 1} \right\}$$

so we have that

$$C'(a) > (1 - \psi) \mathbb{E}_\zeta \left[\frac{Q'(\theta, a, \zeta)}{Q^2(\theta, a, \zeta)} \right] B > (1 - \psi) AB > 0$$

where the last inequality follows from the uniqueness condition for the price and the fact that $dB/dq > 0$. It follows that for each $a > 0$, $C'(a) > A > 0$. Since $C(a)$ is a convex function, $C'(a)$ is monotonically increasing in a , and therefore invertible. Then let $a' \equiv C'^{-1}(A)$. Since $A > 0$ and $C(0) = 0$, $a' > 0$. Consider $a \in (0, a')$. Since the function $C'(a)$ is increasing, we have that $C'(a) < A$, which is a contradiction. This establishes that for $\theta > \bar{\theta}$, there exists some $a > 0$ such that the first order condition holds with equality. As a result, there cannot be an equilibrium without manipulation. \square

Proof of Lemma 1. Recall the expression for the posterior default probability conditional on x , y and z , equation (2.16). Note that this can be written as

$$\Pi(\theta^*(q), x, y, z) = \frac{A(\theta^*(q), x, y, z)}{A(\theta^*(q), x, y, z) + B(\theta^*(q), x, y, z)}$$

where

$$A(\theta^*(q), x, y, z) \equiv \int_{-\infty}^{\theta^*(q)} \sqrt{\alpha_{x,z}} \phi[\sqrt{\alpha_{x,z}}(u - \delta x - (1 - \delta)z)] \sqrt{\alpha_y} \phi[\sqrt{\alpha_y}(u + a(u) - y)] du$$

$$B(\theta^*(q), x, y, z) \equiv \int_{\theta^*(q)}^{+\infty} \sqrt{\alpha_{x,z}} \phi[\sqrt{\alpha_{x,z}}(u - \delta x - (1 - \delta)z)] \sqrt{\alpha_y} \phi[\sqrt{\alpha_y}(u + a(u) - y)] du$$

We want to show that $\Pi_y \equiv \partial\Pi/\partial y < 0$. $\Pi_y < 0$ if and only if

$$\frac{A_y(\theta^*(q), x, y, z)}{A(\theta^*(q), x, y, z)} < \frac{B_y(\theta^*(q), x, y, z)}{B(\theta^*(q), x, y, z)} \quad (2.29)$$

where

$$A_y(\theta^*(q), x, y, z) \equiv -\sqrt{\alpha_y} \int_{-\infty}^{\theta^*(q)} \sqrt{\alpha_{x,z}} \phi[\sqrt{\alpha_{x,z}}(u - \delta x - (1 - \delta)z)] \sqrt{\alpha_y} \phi'[\sqrt{\alpha_y}(u + a(u) - y)] du$$

$$B_y(\theta^*(q), x, y, z) \equiv -\sqrt{\alpha_y} \int_{\theta^*(q)}^{+\infty} \sqrt{\alpha_{x,z}} \phi[\sqrt{\alpha_{x,z}}(u - \delta x - (1 - \delta)z)] \sqrt{\alpha_y} \phi'[\sqrt{\alpha_y}(u + a(u) - y)] du$$

and $\phi'[\sqrt{\alpha_y}(u + a(u) - y)] = -(u + a(u) - y)\phi[\sqrt{\alpha_y}(u + a(u) - y)]$. Then let us define two densities

$$\varphi_A(\theta, q, x, y, z) \equiv \frac{\sqrt{\alpha_{x,z}} \phi[\sqrt{\alpha_{x,z}}(\theta - \delta x - (1 - \delta)z)] \sqrt{\alpha_y} \phi[\sqrt{\alpha_y}(\theta + a(u) - y)]}{\int_{-\infty}^{\theta^*(q)} \sqrt{\alpha_{x,z}} \phi[\sqrt{\alpha_{x,z}}(u - \delta x - (1 - \delta)z)] \sqrt{\alpha_y} \phi[\sqrt{\alpha_y}(u + a(u) - y)] du}, \text{ for } \theta > \theta^*(q)$$

$$\varphi_B(\theta, q, x, y, z) \equiv \frac{\sqrt{\alpha_{x,z}} \phi[\sqrt{\alpha_{x,z}}(\theta - \delta x - (1 - \delta)z)] \sqrt{\alpha_y} \phi[\sqrt{\alpha_y}(\theta + a(u) - y)]}{\int_{\theta^*(q)}^{+\infty} \sqrt{\alpha_{x,z}} \phi[\sqrt{\alpha_{x,z}}(u - \delta x - (1 - \delta)z)] \sqrt{\alpha_y} \phi[\sqrt{\alpha_y}(u + a(u) - y)] du}, \text{ for } \theta \leq \theta^*(q)$$

This enables us to re-write equation (2.29) as

$$\int_{-\infty}^{\theta^*(q)} [u + a(u)] \varphi_A(u, q, x, y, z) du < \int_{\theta^*(q)}^{+\infty} [u + a(u)] \varphi_B(u, q, x, y, z) du \quad (2.30)$$

The inequality follows from the fact that $\theta + a(\theta)$ is monotonically increasing in θ . This establishes that the posterior default belief is decreasing in y . \square

Corollary 4. *The posterior belief of any private agent $\Pi(\theta, x, y, z)$ is decreasing in x and in z .*

Proof. The logic of the proof is the same as in the proof of Lemma 1. \square

Proof of Lemma 2. Consider the equation implicitly defining the price correspondence $Q[y, z, a(\cdot)]$

$$\Pi[\theta^*(q), z - \gamma/\sqrt{\alpha_x}, y, z, a(\cdot)] - \tilde{q}(q) = 0 \quad (2.31)$$

Begin by observing that the right hand side of (2.31) is bounded below by 0 and above by 1, but the left hand side is decreasing in q and it diverges to $+\infty$ as $q \rightarrow \underline{q}$ and to $-\infty$ as $q \rightarrow \bar{q}$. It follows that the price correspondence is non-empty for any pair $(y, z) \in \mathbb{R}^2$.

Next, note that since the threshold function $\theta^*(q)$ is decreasing but the posterior default belief increases in θ^* , $\partial\Pi/\partial q < 0$

$$\frac{\partial\Pi}{\partial q} = -\frac{\eta}{\kappa q^2} \frac{\sqrt{\alpha_{x,z}}\phi[\sqrt{\alpha_{x,z}}(\theta^*(q) + \delta\gamma/\sqrt{\alpha_x} - z)]\sqrt{\alpha_y}\phi[\sqrt{\alpha_y}(\theta^*(q) + a(\theta^*(q)) - y)]}{\int_{-\infty}^{+\infty} \sqrt{\alpha_{x,z}}\phi[\sqrt{\alpha_{x,z}}(u + \gamma/\sqrt{\alpha_x} - z)]\sqrt{\alpha_y}\phi[\sqrt{\alpha_y}(u + a(u) - y)]du}$$

The second term of this product is the posterior density $\pi[\theta, z - \gamma\sqrt{\alpha_x}, y, z, a(\cdot)]$, which is bounded above by 1, so $\partial\Pi/\partial q > -\eta/(\kappa q^2)$.

Now consider the left-hand side of (2.31) as a function of q

$$H : (\underline{q}, \bar{q}) \rightarrow \mathbb{R}$$

$$q \mapsto \Pi[\theta^*(q), z - \gamma/\sqrt{\alpha_x}, y, z, a(\cdot)] - \tilde{q}(q)$$

and observe that since both the function \tilde{q} and the function Π are decreasing in q , $\lim_{q \rightarrow \bar{q}} H(q) > 0$ and $\lim_{q \rightarrow \underline{q}} H(q) < 0$. As a result, a sufficient condition for price uniqueness is that $dH/dq > 0$ for all $q \in (\underline{q}, \bar{q})$. Now differentiating (2.31) with respect to q we obtain

$$\frac{dH}{dq} = \frac{\partial\Pi}{\partial q} + \frac{1}{\eta\beta} \quad (2.32)$$

which is strictly positive if

$$\frac{1}{\eta\beta} > \sup_{q \in (\underline{q}, \bar{q})} -\frac{\partial\Pi}{\partial q}$$

Since $\partial\Pi/\partial q$ is bounded above by 1, a sufficient condition for this inequality to hold is that

$$\frac{1}{\eta\beta} > \frac{\eta}{\kappa q^2} \quad (2.33)$$

which ensures price uniqueness.

The same condition also guarantees that the price function $Q(y, z)$ be decreasing in y . To see this, observe that

$$\frac{\partial Q}{\partial y} = -\frac{\frac{\partial\Pi}{\partial y}}{\frac{1}{\eta\beta} + \frac{\partial\Pi}{\partial q}} > 0$$

Under condition (2.33), the denominator in this ratio is positive. We have shown earlier that $\partial\Pi/\partial y < 0$, so the numerator is positive. It follows that the equilibrium

price is increasing in y . □

Corollary 5. *Under Assumption 2, the price function is increasing in z .*

Proof of Corollary 5. The corollary follows from Corollary 4 and Lemma 2. □

Proof of Proposition 2. We conjecture and verify that in equilibrium $\theta + a(\theta)$ is an increasing function. We consider first values of θ such that $a(\theta) > 0$, and then values of θ such that $a(\theta) = 0$.

By Proposition 1, we know that $a(\theta) > 0$ for some θ . Then it must be the case that $a = a(\theta)$ satisfies

$$a \in \operatorname{argmax}_{m \geq 0} \left\{ \mathbb{E}_{(y,z)} \left[\theta - \frac{1}{Q(z,y)} \mid \theta, m \right] B - C(m) \right\} \quad (2.34)$$

provided that

$$\begin{aligned} & \mathbb{E}_{(y,z)} \left[\theta - \frac{1}{Q(z,y)} \mid \theta, a \right] B - C(a) \geq \\ & \max_{m \geq 0} \left\{ \mathbb{E}_{(y,z)} \left[(1 - \kappa)\theta - \frac{1 - \eta}{Q(z,y)} \mid \theta, m \right] B - C(m) \right\} \end{aligned}$$

and

$$a \in \operatorname{argmax}_{m \geq 0} \left\{ \mathbb{E}_{(y,z)} \left[(1 - \kappa)\theta - \frac{1 - \eta}{Q(z,y)} \mid \theta, m \right] B - C(m) \right\} \quad (2.35)$$

if the inequality is reversed.

Given that y and z are independent conditional on θ , since the optimal manipulation a satisfies either (2.34) or (2.35), it must be the case that a is consistent with either

$$\begin{aligned} & \alpha_y \int_{-\infty}^{+\infty} B \cdot \mathbb{E}_z \left[\theta - \frac{1}{Q(z,y)} \mid \theta \right] (y - \theta - a) \sqrt{\alpha_y} \phi[\sqrt{\alpha_y}(y - \theta - a)] dy \\ & - C'(a) = 0 \end{aligned} \quad (2.36)$$

or

$$\begin{aligned} & \alpha_y \int_{-\infty}^{+\infty} B \cdot \mathbb{E}_z \left[(1 - \kappa)\theta - \frac{1 - \eta}{Q(z,y)} \mid \theta \right] (y - \theta - a) \sqrt{\alpha_y} \phi[\sqrt{\alpha_y}(y - \theta - a)] dy \\ & - C'(a) = 0 \end{aligned} \quad (2.37)$$

Let's now use the change of variables $u \equiv \sqrt{\alpha_y}(y - \theta - a)$. Then equations (2.36)

and (2.37) are equivalent to

$$\int_{-\infty}^{+\infty} f^j(\theta, a, u) u \phi[u] du - C'(a) = 0 \quad (2.38)$$

where $j \in \{1, 2\}$ and

$$f^1(\theta, a, u) \equiv \sqrt{\alpha_y} \mathbb{E}_z[\theta - Q^{-1}(\theta + a + u/\sqrt{\alpha_y}, z)|\theta]B$$

$$f^2(\theta, a, u) \equiv \sqrt{\alpha_y} \mathbb{E}_z[(1 - \kappa)\theta - (1 - \eta)Q^{-1}(\theta + a + u/\sqrt{\alpha_y}, z)|\theta]B$$

Differentiating the first order condition with respect to θ yields

$$\int_{-\infty}^{+\infty} \left[\frac{\partial f^j}{\partial \theta} + \frac{\partial f^j}{\partial a} \frac{da}{d\theta} \right] u \phi[u] du - C''(a) \frac{da}{d\theta} = 0$$

Now observe that

$$\frac{\partial f^j}{\partial a} = \sqrt{\alpha_y} \cdot \mathbb{E}_v \left[[1 - h(j)] Q^{-2} \frac{\partial Q}{\partial y} \middle| \theta \right] B > 0$$

$$\begin{aligned} \frac{\partial f^j}{\partial \theta} &= \sqrt{\alpha_y} \cdot \mathbb{E}_v \left[1 - k(j) + [1 - h(j)] Q^{-2} \left(\frac{\partial Q}{\partial y} + \frac{\partial Q}{\partial z} \right) \right] B \\ &= \sqrt{\alpha_y} [1 - k(j)] B + \frac{\partial f^j}{\partial a} > 0 \end{aligned}$$

after the change of variable $v = \sqrt{\alpha_z}(z - \theta)$, so $Q = Q(\theta, a, u, v)$, defined as $Q(\theta, a, u, v) \equiv Q(\theta + v/\sqrt{\alpha_z}, \theta + a + y/\sqrt{\alpha_y})$. The distribution of v is thus a standard Gaussian random variable. The inequalities follow from $\partial Q/\partial y > 0$ and $\partial Q/\partial z > 0$.

Re-arranging

$$\frac{da}{d\theta} = \frac{-\int_{-\infty}^{+\infty} \frac{\partial f^j}{\partial \theta} u \phi[u] du}{\int_{-\infty}^{+\infty} \frac{\partial f^j}{\partial a} u \phi[u] du - C''(a)} = \frac{-\int_{-\infty}^{+\infty} \left(\sqrt{\alpha_y} [1 - k(j)] B + \frac{\partial f^j}{\partial a} \right) u \phi[u] du}{\int_{-\infty}^{+\infty} \frac{\partial f^j}{\partial a} u \phi[u] du - C''(a)}$$

Now to establish the monotonicity result for this particular θ , we need $1 + da(\theta)/d\theta > 0$. Therefore we need to show that

$$\frac{-\sqrt{\alpha_y} [1 - k(j)] B - C''(a)}{\int_{-\infty}^{+\infty} \frac{\partial f^j}{\partial a} u \phi[u] du - C''(a)} > 0 \quad (2.39)$$

Now since a is optimal, a satisfies the second order condition

$$\int_{-\infty}^{+\infty} \frac{\partial f^j}{\partial a} u \phi[u] du - C''(a) < 0 \quad (2.40)$$

as well as the first order condition, equation (2.38). This guarantees that the denominator of the left-hand side of inequality (2.39) be negative. The numerator is negative since (1) $\alpha_y[1 - k(j)]B \geq 0$ and (2) the manipulation cost function is convex, which implies that $C''(a) > 0$. Hence, the ratio is positive. This establishes the monotonicity result for any θ such that $a(\theta) > 0$.

Now consider θ such that $a(\theta) = 0$. This manipulation action satisfies

$$\int_{-\infty}^{+\infty} f^j(\theta, 0, u)u\phi[u]du < 0 \quad (2.41)$$

since $C'(0) = 0$. Consider marginally increasing θ to θ' such that $\theta' - \theta < \varepsilon$ for some arbitrarily small $\varepsilon > 0$. Since $\partial f/\partial \theta > 0$, the left-hand side of equation (2.41) increases

$$\int_{-\infty}^{+\infty} f^j(\theta, 0, u)u\phi[u]du < \int_{-\infty}^{+\infty} f^j(\theta', 0, u)u\phi[u]du$$

If it is the case that $\int_{-\infty}^{+\infty} f^j(\theta', 0, u)u\phi[u]du < 0$, $a(\theta') = 0$, and the function $\theta + a(\theta)$ is locally monotonic because $\theta < \theta'$. If, on the other hand, $\int_{-\infty}^{+\infty} f^j(\theta, 0, u)u\phi[u]du \geq 0$, the new optimal manipulation action must be strictly positive, $a(\theta') > 0$, in which case the function $\theta + a(\theta)$ is locally monotonic because $\theta' > \theta$ and $a(\theta') > a(\theta) = 0$. This establishes the monotonicity result for any θ such that $a(\theta) = 0$ and it thereby concludes the proof. \square

Proof of Proposition 3. Consider the necessary condition for optimality

$$\int_{-\infty}^{+\infty} \mathbb{E}_z \left[[1 - h(j)]Q^{-2}(\theta + a + u/\sqrt{\alpha_y}, z) \frac{\partial Q}{\partial y} \Big| \theta, a \right] \phi(u)du - C'(a) = -\mu, \quad \mu \geq 0$$

and take the limit on both sides as $\alpha_y \rightarrow +\infty$. We get that $C'(a) = \mu$ for all θ , so $a(\theta) = 0$ for all $\theta \in \mathbb{R}$.¹¹ \square

Proof of Corollary 3. The proof follows from the proofs of Proposition 5 and of Lemma 2. \square

2.7.2 A variant with exogenous prices

In this subsection, we study manipulation incentives, equilibrium manipulation and manipulation effectiveness under the assumption that the bond price is exogenously given. This is interesting on two separate accounts. First, it enables us to further investigate whether a manipulation technology that operates on a source of information that helps coordination is more efficient than a technology that operates on

¹¹The optimality condition holds for any monotone selection from $Q(y, z)$.

private information. As we have seen, in models with endogenous prices, those act both as private information aggregators and coordination devices. As a result, manipulating private information may have the same advantages as manipulating public information. To test this hypothesis, we shut down prices, so the manipulation of private information no longer affects coordination. In addition, evidence on manipulation and misreporting suggests that the phenomenon may be more widespread in countries with lower levels of financial development that can be modeled as price takers in international financial markets.

Suppose then that the bond price q is exogenously given. When this is the case, the government faces uncertainty with respect to aggregate bond demand B , which is a random function of the public signal y . Governments manipulate to affect the identity of the marginal agent, x^* , so as to borrow more, rather than to decrease their borrowing costs and default risk. In fact, the government faces no uncertainty as to the possibility of default, since by the default rule (as given by equation (2.13) in the main body) the outcome is a function of the fundamentals and the price, both of which are known to the government.

Absent manipulation, the posterior default belief can be written as

$$\Pi[\theta^*(q), x, y] = \Phi[\sqrt{\alpha}(\theta^*(q) - \psi x - (1 - \psi)y)] \quad (2.42)$$

with $\psi \equiv \alpha_x/\alpha$ and $\alpha \equiv \alpha_x + \alpha_y$. By the indifference condition of the private sector we then get

$$x^*(y, q) = \frac{\eta}{\psi\kappa} \frac{1}{q} - \frac{1 - \psi}{\psi} y - \frac{\Phi^{-1}[\tilde{q}(q)]}{\psi\sqrt{\alpha}} \quad (2.43)$$

since $\theta^*(q)$ is given by (2.13).

If the government manipulates public information, private information is given by (2.1) and (2.2), while public information by (2.3). The posterior default belief becomes

$$\Pi[\theta^*(q), x, y] = \frac{\int_{-\infty}^{\theta^*(q)} \sqrt{\alpha_x} \phi[\sqrt{\alpha_x}(u - x)] \sqrt{\alpha_y} \phi[\sqrt{\alpha_y}(u + a(u) - y)] du}{\int_{-\infty}^{+\infty} \sqrt{\alpha_x} \phi[\sqrt{\alpha_x}(u - x)] \sqrt{\alpha_y} \phi[\sqrt{\alpha_y}(u + a(u) - y)] du} \quad (2.44)$$

The private information threshold $x^*(y, q)$ is found by solving the private sector indifference condition

$$\Pi[\theta^*(q), x, y] = \tilde{q}(q)$$

where $\Pi(q, x, y)$ is given by (2.44) and the default threshold $\theta^*(q)$ by (2.13). The

government faces uncertainty about the size of bond demand, which is now given by

$$B(q, y, s) = \Phi[\sqrt{\alpha_x}(\theta^*(q) + (1 - \omega)s - x^*(y, q))] \quad (2.45)$$

Accordingly, the government now solves

$$\max_{a \geq 0} \left\{ \left((1 - k)\theta - \frac{1 - h}{q} \right) \mathbb{E}_{y,s} [B(q, y, s) | \theta, a] - C(a) \right\} \quad (2.46)$$

Unlike in the model with endogenous prices, the government now manipulates so as to affect the distribution of the mass of lenders, $B(q, y, s)$, by altering the distribution of the marginal agent $x^*(q, y)$. Suppose that the mean of the public signal y , $\theta + a(\theta)$, is increasing in θ . Then the same logic as in the proof of Lemma 1 establishes that the posterior default belief of the market is (i) decreasing in x and (ii) decreasing in y . As a result, the marginal signal is also decreasing in y , which in turn makes the mass of lenders increasing in y . Therefore, there are incentives to manipulate. Governments manipulate to borrow more rather than to decrease their borrowing costs.

An example of such incentives is provided in the left panel of Figure 2-15, which is drawn for the same information structure as in the baseline scenario spelled out in the first row of Table 2.1. We plot the optimal manipulation action $a(\theta, q)$ as a function of θ for different values of q and different assumptions about the beliefs of the market. Specifically, the dashed lines correspond to naive expectations, and the continuous lines to rational expectations. The figure suggests that the absence of market signals increases the incentives to manipulate. The negative externality effect pushing for more manipulation is strong enough to just offset the rational expectations effect pushing for less manipulation, for all levels of q being considered. Moreover, as long as the bond price q is sufficiently large, governments manipulate more when the market has rational expectations than when it has naive expectations, which implies that the negative externality effect more than offsets the rational expectations effect. In the baseline scenario with endogenous prices presented in Fig. 2-4, the reverse is true since the rational expectations effect dominates instead. The negative externality effect is only strong enough to outweigh the rational expectations effect provided the endogenously biased signal is sufficiently precise, as per Fig. 2-9. Hence, it looks like the presence of market signals may work to dampen the externality effect on manipulation incentives. Intuitively, the more sources of information private sector agents can rely on, the better the quality of their inference about the fundamentals, the harder it is to fool them.

Unlike in the model with endogenous prices, most governments who choose a

strictly positive manipulation action end up being better off with access to the manipulation technology than without, as shown in the right panel of Fig. 2-15. Moreover, the governments with the strongest manipulation incentives are now also those who benefit the most from equilibrium manipulation. Absent endogenous prices, there are still losers from manipulation, especially for high values of the bond price. However, this time around the losers are not enduring the negative externality. They are actively offsetting it by choosing large manipulation actions that are costly.

Moreover, the manipulation incentives increase with the bond price q . This is not surprising, since a lower interest rate increases the marginal benefit of manipulation, as shown by equation (2.46). Hence, the higher q , the more biased the public signal y .

If the government manipulates private information, the private signal x_1 is given by (2.1), the private signal x_2 is given by (2.23) and the public signal y by (2.3). The posterior default belief becomes

$$\Pi[\theta^*(q), x, y] = \frac{\int_{-\infty}^{\theta^*(q)} \sqrt{\alpha_x} \phi[\sqrt{\alpha_x}(u + \omega a(u) - x)] \sqrt{\alpha_y} \phi[\sqrt{\alpha_y}(u - y)] du}{\int_{-\infty}^{+\infty} \sqrt{\alpha_x} \phi[\sqrt{\alpha_x}(u + \omega a(u) - x)] \sqrt{\alpha_y} \phi[\sqrt{\alpha_y}(u - y)] du} \quad (2.47)$$

The private information threshold $x^*(y, q)$ is found by solving the private sector indifference condition

$$\Pi(q, x, y) = \tilde{q}(q)$$

where $\Pi(q, x, y)$ is given by (2.47) and the default threshold $\theta^*(q)$ by (2.13). Bond demand is now given by

$$B(q, y, s, a) = \Phi[\sqrt{\alpha_x}(\theta^*(q) + (1 - \omega)s + \omega a - x^*(y, q))] \quad (2.48)$$

so the government's problem becomes the government now solves

$$\max_{a \geq 0} \left\{ \left((1 - k)\theta - \frac{1 - h}{q} \right) \mathbb{E}_{y,s} [B(q, y, s, a) | \theta] - C(a) \right\} \quad (2.49)$$

As in the case where the government manipulates the mean of exogenous public information y , the marginal benefit from manipulation increases with q . Hence, as shown in the left panel of Figure 2-16, the higher q the more the government manipulates.

The figure also highlights that in the absence of endogenous prices, changing the type of manipulation technology the government has access to has minimal impact on manipulation incentives, equilibrium manipulation and the impact of manipulation on average borrowing. This suggests that the differences in incentives and equilib-

rium manipulation observed across the two different manipulation technologies for the case with endogenous prices may be due to the coordination role of prices.

2.7.3 Manipulation to affect default risk

In this subsection, we present simulation results for an economy where the government manipulates so as to decrease default risk. Specifically, we assume that the haircut is exogenously given, $h = \eta$, and the government's ex-post payoff is now given by

$$U_G(\theta, q, B) - C(a) = \max \left[\left(\theta - \frac{1}{q} \right) B, 0 \right] - C(a) \quad (2.50)$$

so the government gets a zero payoff in case of default. The default threshold then modifies to

$$\theta^*(q) = \frac{1}{q} \quad (2.51)$$

while everything else is as in the baseline model.

Observe that under these assumptions, the very bad types with $\theta \leq \underline{\theta}$ never manipulate. These governments are sure to default whatever the interest rate, so they optimally choose $a(\theta) = 0$. An example of optimal manipulation for $\theta > \underline{\theta}$ is presented in Figure 2-17. For sufficiently low values of θ , the average price increase accomplished with manipulation is not large enough to compensate for manipulation costs, so these governments do not manipulate either.

As in the baseline model, it still appears to be the case that rational expectations effects dominate negative externalities when it comes to determining the incentives to manipulate. However, unlike in the baseline mode, the types that have the largest incentives to manipulate also stand to benefit the most from manipulation.

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Chapter 3

Trust and firm activity

In this paper I explore the link between trust and the performance of firms, as well as their use of contracts. Firms, especially the large ones, are complex organisations. If they are set up in such a way so as to provide few opportunities for repeated interaction amongst employees, reputational channels may not be very effective at fostering cooperation, given the small chances of future punishment. A higher level of trust may help to sustain cooperation by relaxing this “organisational” constraint, thereby improving firm efficiency. At the same time, if managers require employees to engage in tasks that are difficult or costly to monitor, a higher level of trust ought to improve firm efficiency by reducing incentives to shirk on the job (hypothesis 1). Since a high level of trust has the potential to lessen inefficiencies arising from asymmetric information, one may reasonably expect a higher level of trust to make it easier for delegation to happen within a firm. At a very fundamental level, capital owners may be more likely to delegate managerial responsibilities (hypothesis 2). Managers, in turn, may find it easier to contract out the provision of goods and services (hypothesis 3).

I test these three hypotheses by relying on within-country variations, and I choose Italy as my sample country given the availability of detailed firm-level data from the Unicredit Survey of Manufacturing Firms (USMF). The first issue is the measurement of trust. A common approach in the literature is to use survey-based attitudinal questions such as “Using the responses on this card, could you tell me how much you trust [insert respondent’s nationality] people in general?” (World Values Survey). Unlike behavioural indicators, these questions are hard to interpret, so even if the answers are correlated with the prevailing level of trust in a community, it is still likely that the survey-based measures are ridden with measurement error (Glaeser et al., 2000). To correctly identify the impact of trust on firm activity, therefore, I employ an instrumental variables strategy.

The IV approach I employ in this paper rests on the premise that inasmuch as trust can be thought of as the subjective probability attached to not being cheated, social capital is a determinant of trust. Social capital is defined as the set of advantages and opportunities that accrue to people from being embedded in social networks (Bourdieu, 1986). But membership in certain communities gives rise to informal enforcement mechanisms that can sustain trust. For example, if one thinks of trust as an equilibrium outcome in a society in which nonlegal mechanisms enforce cooperation, better community networks may help increase trust by providing good opportunities to punish non-cooperation (Coleman, 1990; Portes, 1998; Spagnolo, 1999). On the other hand, trust can be thought of as a “primitive” embedded in individual preferences. For example, it could be interpreted as a strong prior belief that other economic agents are going to behave cooperatively in a repeated game (La Porta et al., 1996). Inasmuch as social conditioning through education can shape such beliefs, higher social capital should also make for a higher level of trust (Banfield, 1958). Irrespective of the interpretation, the more social capital, the higher the amount of trust in a community. This correlation makes social capital a good IV candidate, and I can rely on social capital indicators constructed by Guiso, Sapienza, and Zingales (2004), that is, referendum turnout and voluntary blood donations.

Since both firm performance and contracting decisions are likely to be affected by the quality of legal institutions, the key identifying assumption is that social capital does not affect the endogenous choice of the legal system. In principle, a society with better informal enforcement mechanisms embedded in social networks may have a lesser need for good legal enforcement, and vice-versa, so formal and informal institutions may be substitutable. In the case of Italy, however, one can make a case that the legal system was largely imposed by invading armies in the 19th century (Shleifer et al., 2008), thereby lessening concerns that the exclusion restriction may not hold.

I find that controlling for a set of environmental variables and firm characteristics, trust does indeed matter for labour productivity, although larger firms do not appear to benefit more than smaller firms. This is at odds with the findings of La Porta et al. (1996), who find evidence of a strong positive correlation between trust and the performance of large organisations in a cross-country study.

As far as the contracting choices are concerned, I do not find evidence that trust affects either the decision to delegate control of the firm to relatives or professional managers or the choice to hire accountants and auditors to manage the firm’s finances. However, it may be the case that there just isn’t enough cross-sectional variability in my sample to correctly identify these effects. Moreover, since I can-

not control for the price of managerial services, the results are likely to suffer from omitted variable bias.

The rest of this work is organised as follows. Section 2 introduces the empirical strategy. Section 3 describes the data. Section 4 presents the empirical results. Section 5 concludes.

3.1 Empirical strategy

3.1.1 Hypotheses

Economists increasingly interpret trust as a belief that one is not going to be cheated, strong enough to consider engaging in cooperation (Gambetta, 2000). In a game theoretic sense, this kind of subjective belief can arise endogenously in the context of repeated games, where reputation and the threat of future punishment can sustain cooperation as an equilibrium outcome. Experimental research pioneered by Berg et al. (1995) however shows that people can believe they are not going to be cheated even in one-off encounters (Glaeser et al., 2000; Butler et al., 2009; Sapienza et al., 2013). This suggests that trust may be also thought of as a “primitive”, and one that could potentially be transmitted from generation to generation (Tabellini, 2008). Nonetheless, Anderlini and Terlizzese (2013) have studied the equilibrium properties of a canonical version of experimental games. They have shown that trust can be endogenously engendered in a one-off sender-receiver game à la Berg, provided players suffer some cheating cost. In their model, the cost of cheating has both an idiosyncratic component and a component which is driven by the behaviour of others, so the equilibrium level of trust is partly driven by preferences and partly driven by “social norms”.

Given this definition, one might expect higher trust to improve the productivity of firms. For instance, La Porta, Lopez-de-Silanes, Shleifer, and Vishny (1996) claim that trust is most useful in sustaining cooperation amongst economic actors that interact only once or infrequently, as it happens in larger firms in which reputational channels are shut off and there exist few opportunities for future punishment. A greater level of trust thus enables a large firm to be more efficient, by relaxing an “organisational constraint” that would otherwise hurt cooperation between employees. Hence, the first hypothesis I wish to test is whether more trust makes firms more efficient, and whether the effect is stronger for larger firms. Accordingly, I model production using a Cobb-Douglas technology

$$y_{i,t} = \beta_1 k_{i,t} + \beta_2 n_{i,t} + \beta_3 s_{i,t}^{WC} + \beta_4 s_{i,t}^E + \beta_5 t + \beta_6 l + x_{i,t} \gamma + \varepsilon_{i,t} \quad (3.1)$$

where y denotes labour productivity measured as log of real sales per worker; k is the log of capital intensity, that is, real capital per worker; n is the firm size, that is, the log of the number of workers. To account for labour skills, I include the log of the share of white-collar employees, s^{WC} , as well as the log of the share of executives in employees, s^E . The variable t represents trust and l is the quality of law enforcement, measured as the log of the average length of a first degree trial; finally, x is a vector of controls. The vector x includes industry dummies and innovation dummies to control for differences in TFP across firms. x also contains real GDP per capita, an indicator of financial development, the use of checks, and average years of schooling. Economic and financial development have been found to be correlated with trust (Knack and Keefer, 2007; Guiso et al., 2004). As for average schooling in the province, it is likely to have externalities on the behaviour of the firm. These all vary at the province level. Local government in Italy has a three-tier structure. At the lower level, there are municipalities (comuni), which are roughly equivalent to U.S. cities. One level up, there are provinces (province), which correspond to U.S. counties. A collection of provinces makes up a region (regione). Finally, I include survey-wave dummies and year dummies as well as well as firm log age.

Trust also matters because at the very heart of each firm lies a contracting problem under asymmetric information. Capital owners face a choice whether to delegate authority to managers or to retain that authority for themselves, in a world where they cannot tell apart good managers from lucky managers. A greater level of trust is likely to make it easier for owners to delegate authority to managers, thereby lessening the strength of the principal agent problem. My second hypothesis is thus that owners of firms which are located in higher trust communities should be less involved in management than firm owners in lower trust communities.

Relatedly, the Coasian view of the firm (Coase, 1937) implies a positive relationship between trust and the extent to which a firm's decision-makers rely on the market for the provision of goods and services. In this view, the firm always faces an option of "doing things" in house rather than relying on market transactions and contracts. As the level of trust increases, the relative benefit of contracting out productive activities ought to increase too. If a greater level of trust reduces the ex-post inefficiency that may arise in a market transaction, e.g. by reducing the incentive to shirk in an employment contract, then firm decision-makers would have a smaller incentive to do things in house. Hence in communities where the level of trust is greater we should observe a greater propensity for firms to contract out economic activities. This is the last hypothesis that I am going to test.

To investigate whether the last two hypothesis are born out by the data, I esti-

mate Probit models of the probability of delegation to managers and of contracting out

$$\Pr\{D_{i,t} = 1\} = \Phi[\beta_1 T + \beta_2 L + X_{i,t}\gamma] \quad (3.2)$$

$$\Pr\{F_{i,t} = 1\} = \Phi[\beta_1 T + \beta_2 L + X_{i,t}\gamma] \quad (3.3)$$

Here, D is a dummy variable which takes a value equal to 1 if the main capital-owner delegates managerial responsibilities, while F is a dummy variable which is equal to 1 if the firm chooses to contract out financial management services, which means hiring accountants and auditors. X is a vector of firm-level and province-level controls which contains the firm age, size (i.e. number of employees), sales, and proxies for the skill level of the workforce. In addition, X contains measures of financial and economic development, as well as of average education in the province where the firm is registered. Finally, both delegation of managerial responsibilities and of financial management are likely to be affected by the prices of these services, which I cannot control for directly. However, it is reasonable to suppose that the prices would not change much within the same province. Hence, including province fixed effects should absorb the impact of relative prices. Unfortunately, this is not something I can do given that the social capital indicators are measured at the province level. The best I can do is to include some macro-region indicators that correspond to a partition of the Italian territory into five macro-areas: north-west, north-east, centre, south and islands, as per the Italian National Institute of Statistics geographical classification (the north-west is the omitted category). I cannot include region fixed effects because my trust measure varies at the regional level. Of course, this does not eliminate the problem of OVB, but it should at least lessen it.

3.1.2 Measuring trust: an IV approach

Despite the definition of trust given above, most papers in the literature use answers to survey-based attitudinal questions as measures of trust. For example, both the World Values Survey (WVS) and the General Social Survey (GSS) both ask “Generally speaking, do you think that most people can be trusted or that you cannot be too careful in dealing with people?”. Despite its broad use, it is not clear that the answer to this and similar questions are good measures of trust, as they are not based on actual behaviour. Nor is it obvious that experiment-based measures ought to be relied on instead, since in a laboratory setting agents’ behaviour may be distorted by things like experimenter’s scrutiny (Levitt and List, 2007).

In this paper, I pursue an instrumental variables strategy to alleviate the error

in measurement problem associated with using survey-based measures of trust to estimate the impact of trust on the efficiency of firms and their delegation choices. The starting point is the idea that trust is driven by both formal and informal enforcement mechanisms. While formal enforcement lies within the domain of the legal system, informal enforcement mechanisms arise from membership in certain communities. These mechanisms are rooted in “social capital”, defined as the set of advantages and opportunities that accrue to people from being embedded in social networks (Bourdieu, 1986). The nature of the connection between social capital and trust depends on the particular view that one takes on trust. For example, if one interprets of trust as an equilibrium outcome in a society in which nonlegal mechanisms enforce cooperation, better community networks may help increase trust by providing good opportunities to punish non-cooperation (Coleman, 1990; Portes, 1998; Spagnolo, 1999). On the other hand, if trust is interpreted as a “primitive”, inasmuch as social conditioning through education can shape beliefs as shown by Tabellini (2008), higher social capital should also make for a higher level of trust (Banfield, 1958). Irrespective of the interpretation, the more social capital, the higher the amount of trust in a community. This suggests that social capital measures may be good instrumental variables candidates for trust. Specifically, I consider two outcome-based social capital measures collected by Luigi Guiso, Paola Sapienza and Luigi Zingales (GSZ) for their paper on financial development (Guiso et al., 2004), referendum turnout and voluntary blood donations (in Italy). These are thought to be ideal social capital indicators because they are driven by internal norms and social pressures rather than legal or economic incentives.

The key identification assumption is that social capital affects the efficiency of firms and their contracting choices through trust and only through trust. While the correlation between survey-based measures of trust and the GSZ social capital indicators is easily testable, whether the exclusion restriction does or does not hold is a matter for discussion. The main concern here is that the quality of legal institutions likely affects both the efficiency of firms and their choice of delegation, for instance by making it easier and speedier to resolve disputes (Djankov, La Porta, Lopez-Silanes, and Shleifer, 2003). However, it is not inconceivable that social capital affects the endogenous choice of such institutions. In principle, a society with better informal enforcement mechanisms embedded in social networks may have a lesser need for good legal enforcement, and vice-versa, so formal and informal institutions may actually be substitutable. To the extent that the Italian legal system was strongly influenced by the Napoleonic code imposed by invading armies in the 19th century and that legal origins are a good predictor for the quality of law enforcement

as argued by Shleifer, Lopez-de-Silanes, and La Porta (2008), however, one can begin to make a case for the exclusion restriction to hold.

3.2 The data

The firm-level data comes from the “Survey on Manufacturing Firms” administered by Unicredit (an Italian commercial bank, previously known as Mediocredito-Capitalia). I focus on two waves of this survey, the 6th and 7th. These two surveys were administered in 1998 and in 2001, respectively, to a representative sample of Italian manufacturing firms, and they requested information about the three years prior to the survey date (1995-1997 and 1998-2000). While firms with fewer than 500 employees were selected using a stratified sampling design based on industry, size, and location, all firms with more than 500 employees were surveyed. I merged the data from these two surveys, obtaining an unbalanced panel on 6,474 firms, of which 1,025 are present in both waves. In my analysis, I check for the robustness of results to the inclusion of these repeat observations.

Summary statistics for the key firm-level variables are reported in Table 3.2. Average real labour productivity is about 230 thousand 2010 euros per worker. The distribution of productivity is skewed to the right, with a median of 176 thousands and quite a large standard deviation of 218 thousands, about 94% of the mean. The distribution of capital intensity is also right skewed, with a mean of 67 thousand 2010 euros per worker and a median of 41 thousands. There is a lot of cross-sectional variation in capital intensity, with the standard deviation being almost twice the mean. More than 50% of the firms in the sample have had fewer than 50 employees, on average, in the time period I am considering (See Table 3.2). Hence it is not surprising that the mean number of employees is only 28, although the presence of larger firms makes for very large variation in the sample. The mean is much higher than the median, at about 106, and the standard deviation is about three times the mean. On average, white collar workers make up approximately 22% of the workforce, while executives only 4%. Here too there is substantial variation though. The standard deviation of the the share of white-collar workers is 68% of its mean, while for executives the standard deviation is about large as the mean. As far as TFP related variables are concerned, firms are grouped into 22 manufacturing industries. 56.24% of the firms in the sample have product innovations, while 60.53% have process innovations. Fewer firms engage in organisational innovation related to either product innovation, 19.76%, or process innovation, 31.8%.

As far as contracting is concerned, the surveys collect information on whether

the main capital holder does or does not retain direct control of the firm. Control may be delegated to other capital owners (who are very likely to be relatives) or to professional managers. 7.8% of the firms in the sample have main capital owners that have chosen not to retain control. In addition, the questionnaires also included a question about the management of firm finances. A small number of firms, 3.2% of the sample, choose to contract out financial management to accountants and auditors.

Crucially, the surveys also contain information about the “administrative unit” where each firm is registered. Local government in Italy has a three-tier structure. At the lower level, there are municipalities (*comuni*), which are roughly equivalent to U.S. cities. One level up, there are provinces (*province*), which correspond to U.S. counties. Finally, a collection of provinces makes up a region (*regione*). There are 20 regions and about 100 provinces in the country. The Unicredit survey contains data on the province of registration of each firm, which makes it possible to attach trust and social capital measures to the firms in the sample.

The measure of trust I use in this paper comes from the 1989 and 1999 editions of the World Values Survey. The WVS is a worldwide investigation of sociocultural and political change conducted by a network of social scientist at universities all around the world. In each of the two surveys, a sample of about 2,000 Italians were asked the question “Using the responses on this card, could you tell me how much you trust other Italians in general?”, with answers ranging in intensity from 1 to 5. The dataset also contains information about the region where each response has been collected. As a result, after converting responses into an index, I can compute regional averages and merge with the firm-level data. I have 19 regions in my sample. As shown in Table 3.2 there is little cross-sectional variability in trust, which has a standard deviation of 0.02, only 3% of its mean, 0.67.

The two instruments I use for trust are two social capital measures collected by Guiso et al. and employed in their paper on social capital and financial development. The first instrument is an average of referendum turnout between 1946 and 1989. The second is blood donations, measured in 16-ounce bags collected per inhabitant in 1995. Both these indicators vary at the province-level. The social capital indicators display greater cross-sectional variability than trust. The standard deviation of turnout is 7% of its mean, which is high, at 85%. The average number of blood bags donated has a much higher standard deviation, at about 57% of its mean, which is 3.5 bags per hundred people.

There are a total of 88 provinces in my sample. For each province, the GSZ dataset also contains information about the quality of law enforcement, average

education, and financial development. I have already discussed why the quality of law enforcement ought to matter for productivity and the use of contracts. While the regressions control for labour skills by including the shares of white-collar employees as well as the share of executives in total employees, average education may have externalities on the behaviour of firms. Financial development likely matters for firms' contracting decisions as well as for their efficiency. In particular, the dataset contains the average number of years of schooling in the province in 1981, the average length (in years) of a first degree trial and the households that use checks in the province as a share of those included in the Bank of Italy's Survey of Household Income and Wealth (SHIW). Education averages 7.7 years, with a standard deviation of about 0.6 years, approximately 8.5% of the mean. In the sample, a first degree trial lasts on average 3.2 years, with a standard deviation of about one year. Trials can go on much longer though, up to 8 years in some provinces. Although 58.6% of households used checks, there is substantial variability in the sample, with a standard deviation of 14.7 percentage points and the use of checks varying between 13% and 80% of the households in the SHIW.

Finally, I control for economic development because it has been shown to be correlated with both trust (Knack and Keefer, 2007) and financial development (Guiso, Sapienza, and Zingales, 2004). I augment the set of province-level variables with real per capita GDP in 2001 (the most relevant census year given the time period I am considering) which I compute based on nominal GDP data provided by Unioncamere, the representative body for Italian Chambers of Commerce (nominal GDP per capita). After deflating with the Italian CPI (provided by the OECD), I obtain an average level of GDP of about 16,600 2010 euros per person. There is quite a bit of cross-sectional deviation, with the standard deviation of GDP equal to roughly 20% of its mean, at about 3,300 2010 euros.

By claiming that I can test my hypotheses using this sample, I am implicitly assuming that social capital "at origin" matters for firm performance and size. This will be true as long as the firms in the sample concentrate most of their activities in the area where they are registered. If a firm, for instance, were registered in the Treviso province but delocalised most of its production in Romania, then at a minimum average social capital in Romania would also likely matter for the firm's performance. This is not a small concern, given recent trends to delocalising production in the Italian manufacturing sector. Recent years have witnessed an expansion of this process, with medium-sized enterprises joining in along with larger firms. Survey evidence shows that between 2001 and 2006, 9.9% of Italian medium and large enterprises transferred abroad economic activities previously carried out

in Italy (Palmieri, 2008). The increasing importance of delocalisation is reflected in the development of the Unicredit survey, which has contained a question on delocalisation since 2001 (“Between 1998 and 2000, has the firm delocalised production in Eastern Europe (Poland, Czech Republic, Slovakia, Hungary, Romania, Bulgaria) and in former Yugoslavia?”). Out of the firms in my sample, 3,504 were surveyed in 2001. Of the 3,368 which answered the delocalisation question, only 78 (2.26%) had delocalised.

The hypotheses I introduced on the relationship between social capital, trust and “contracts”, on the other hand, imply that what matters are the levels of social capital and trust embedded in and perceived by owners and managers. Owners choose whether to delegate, while managerial assessment determines whether a firm should contract out activities or rather carry them out in house. If we think of social capital as the norms of behaviour that are imprinted with education, firms run by managers that were brought up in higher social capital/higher trust areas ought to rely on the market more than firms controlled by managers “imprinted” in lower social capital areas, all things equal. Similarly, owners who were brought up in higher social capital/trust communities should display a greater preference for delegation. On the other hand, if we think of social capital as “social and peer pressure” then what matters is the level of social capital in the communities where owners and managers carry out their professional activities. Unfortunately, the Unicredit data does not enable me to distinguish between these possibilities. The survey does not collect information on the geographical origin of owners and managers. Nevertheless, concern with the issue of social capital of and trust embedded in and perceived by owners and managers may be mitigated by taking into account the nature of Italian businesses in the sample. In fact, most firms in the sample are owned by private individuals (for 74.02% of the firms, the main capital-owner is a private individual) who also tends to retain control of the firm (89.33% of the firms in the sample are run directly by the main capital holder). Hence the concern does not arise for a substantial share of the sample.

3.3 Results

3.3.1 Trust and labour productivity

In this section I present the empirical results on the impact of trust on labour productivity, measured as the log real sales (in thousands of 2010 euros) per worker. The point estimates represent elasticities.

Table 3.4 reports estimates of the Cobb-Douglas production function, equation (3.1). As discussed in Section 3.1, there are three kinds of explanatory variables. In addition to the usual firm-specific covariates (i.e. capital intensity, labour, labour skills, age, dummies for innovation and the industry the firm belongs to) I include two “institutional” variables (trust and the quality of legal institutions) as well as a set of province-level controls (per capita GDP, average education, financial development).

OLS estimates suggest that higher trust does indeed increase labour productivity. I find that a 1-percent increase in the trust index increases labour productivity by about 1.24 percentage points, and that the effect is significant at the 5% level (Column I).

Potential measurement error in trust implies that there may be attenuation bias, so the OLS estimate could be too low. To correct for this, I re-estimate the production function using two-stages least squares (2SLS), with turnout and blood donations used as instruments for trust. The reduced form regression reported in Table 3.3 (Column I) shows that both variables are correlated with trust, and that the correlations are significantly different from zero at the 5% and 10% level, respectively.

The 2SLS estimate of the elasticity of labour productivity with respect to the trust index (Column II) is about 4.6%, so it is indeed higher than the OLS estimate while still being significantly different from zero (at the 5% level). When I re-estimate the productivity equation with 2SLS on the set of firms that are only sampled in either the 6th or 7th wave of the USMF (but not both), the coefficient on trust is still positive and significant, although now at the 10% level. The point estimate is still approximately a 4.6% elasticity. As for the other variables, the presence of an efficient technology for dispute resolution does not appear to significantly affect labour productivity, although the coefficient on judicial inefficiency has the right sign. Per capita GDP, years of education and financial development also do not appear to make a difference to productivity. Capital intensity, labour skills and age of the firm are all found to significantly increase labour productivity at the 1% level. There appear to be diminishing returns to labour: the labour elasticity is negative and also significant at the 1% level.

A common problem found when estimating production functions is that at least a part of total factor productivity is going to be observed by the firm at an early enough point in time to change the factor input decision (Arnold, 2005). If TFP is not included in the regression, or if it is measured with error, capital intensity and labour are going to be endogenous in the production equation, causing bias in the structural equation estimates. Olley and Pakes (2006) suggest a semi-parametric

estimator which uses the firm's investment decision to proxy unobserved productivity shocks.¹ Under the assumption that investment is monotonic in productivity, the Olley-Pakes estimator is consistent. Column III reports estimates obtained following this method as a robustness check. Correcting for endogeneity of capital and labour does not affect the significance of the elasticity of productivity with respect to trust, although the point estimate increases a bit, from 4.6% to 5.2%. A similar patterns applies to the other estimates, which are robust to re-estimation with the Olley-Pakes procedure. The point estimates are also robust to the exclusion of the firms which are sampled in both the 6th and 7th wave of the survey (Column VI).

Trust does not appear to make more of a difference to the productivity of larger firms. I split the sample into three size categories based on the number of employees: small firms (1-20), medium firms (21-250), and large firms (251+). I then estimate the production function including a full set of interactions between the trust index and firm size (Column IV) and check that the results are robust to the exclusion of firms which are sampled in both waves of the survey (Column VII). Small firms are the omitted category. The interaction coefficients have the right sign (positive), but they are not significant, except for the one of small firms which is only significant at the 10% level and not robust to the exclusion of firms that are sampled twice (Column VII). This result is at odds with the evidence provided by La Porta, Lopez-de-Silanes, Shleifer, and Vishny (1996). As a measure of firms' success, these authors look at the ratio of sales to GNP of the 20 largest (by sales) publicly traded companies in a sample of 40 countries. Their measure of trust is also derived from the WVS. However, they find that it has a positive and significant (at the 10% level) effect on performance. My results suggest that this correlation may be spurious. Within-country data enables one to do a cleaner test of the hypothesis that trust affects the performance of large organisations, given that one implicitly controls for a host of institutional factors that affect firm performance and may be correlated with trust. As these cannot be easily picked up in a cross-country regression, the cross-country correlation between trust and performance is likely to be driven by such factors rather than by trust itself.

¹ Consider a simple estimation equation of the production function, $y_{it} = \beta l_{i,t} + \gamma k_{it} + \varepsilon_{it} + \omega_{it}$, with ω_{it} the part of the error term that is observed by the firm sufficiently early to affect its factor choices. The first step of the procedure estimates $y_{it} = \beta l_{i,t} + \phi_t + \varepsilon_{it}$, with $\phi_t = \gamma k_{it} + h_t(i_{it}, k_{it})$ and $h_t(i_{it}, k_{it}) = \omega_{it}$. The function $h(\cdot)$ is the inverse of the (unknown) optimal investment function, $i_t(k_{it}, \omega_{it})$. $i(\cdot)$ is invertible since investment is monotonic in the capital stock. In the first step, then, one obtains all coefficients except for that on capital (γ) using a polynomial approximation for the function ϕ . In the second step, one estimates $V_{it} = \gamma k_{it} + g(\phi_{t-1} - \gamma k_{t-1}) + \mu_{it} + \varepsilon_{it}$, with $V_{it} = y_{it} - \hat{\beta} l_{i,t}$, $g(\cdot)$ an unknown function which is approximated with higher-order polynomials in lagged ϕ and k , and μ_{it} an efficiency surprise. The equation is estimated with non-linear least squares and yields $\hat{\gamma}$.

Since its very inception, the literature on social capital and trust in Italy has pointed out the existence of a “social capital gap” between the North and the South of Italy (for a review, see Guiso et al., 2008). One would thus a priori expect firms located in southern provinces to be less efficient. However, there may be other differences between the north and the south (for instance, the relative presence of organised crime) which matter to firm performance and are correlated with trust. In order to explore the possibility that the effects observed may be driven by such factors, I re-estimate the baseline regression by interacting trust with an indicator variable for the location of the firm (Column V). The omitted category is being registered in a southern province. I do not find a significant effect of the geographical indicators, although the interaction between trust and the indicator variable for being located in the north is negative, as expected. Moreover, the estimates do not change much from the baseline (Column II), thereby suggesting that the observed effect is driven by trust itself rather than by other factors which differ across north and south and are correlated with trust. Again, the estimates are robust to the exclusion of firms which have been sampled twice (Column VIII).

3.3.2 Trust and management choices

In this section I present empirical results on the impact of trust on the probability that firms contract out managerial services, whether it be it the general running of the firm or simply the management of its finances.

Before moving on to the analysis, there are two issues that need to be taken into account. First, there may not be enough cross-sectional variation in the categorical variables corresponding to delegation of direct control and to contracting out the management of firm finances to correctly identify the impact of trust on these choices. As shown in Table 3.1, only 7.9% of the firms in the sample are not run directly by the main capital holder. A meager 3.2% hires financial management services. Moreover, I have not been able to control for prices, which are likely to play a role both in the decision to hire managers and to hire accountants and auditors.

These issues notwithstanding, I run a two-step procedure to obtain estimates of β and γ in equation (3.3), the probability that the main capital owner delegates control of the firm. The first step is an OLS regression of trust on the social capital instruments and all other explanatory variables. The second step is a probit of delegation on trust, the residuals from the OLS regression in the first step, and all other explanatory variables. While this control-function method allows the computation of average partial effects (APEs), since the APEs depend on the model coefficients and the asymptotic variance of the coefficient estimators is complicated given the

two-step estimation, the delta method cannot be relied upon to obtain standard errors for the APEs as in a probit with exogenous regressors (Wooldridge, 2010, pp. 585-594).

Table 3.5 reports estimates of β and γ in equation (3.3), the probability that the main capital owner delegates control of the firm. A positive estimate therefore means that a higher value of the corresponding co-variate increases the chances of delegation. Panel A of Table 3.7 reports the APEs, instead. The explanatory variables are the measure of trust, the measure of the quality of formal institutions (judicial inefficiency) as well as a number of firm-level and province-level controls plus industry, wave and year dummies. The firm-level variables are sales, size, and skill-level of the workforce. As for the province-level variables, as before these are per capita GDP, average schooling and the measure of financial development (use of checks). To proxy, at least partially, for the price of managerial services, I include macro-area indicators.

Column I shows that a higher level of trust does not significantly affect the probability of delegation. The coefficient of trust is positive, although the point estimate could be biased by endogeneity. When trust is instrumented with turnout and blood donations, the point estimate for trust again has the right sign but it is still not significantly different from zero (Column II). The picture changes slightly when we take into account how the impact of trust on the probability of delegation changes with firm size (Column III). A higher value of the trust index makes the main holders of capital of medium firms more likely to delegate control to managers than it makes owners of small firms, in line with what one would expect. A unit increase in the trust index causes the probability of delegation to increase by 16.7 percentage points more for medium firms than for small firms, quite a large effects. The interaction coefficient is positive and significant at the 1% level. As shown in Columns IV and V, which replicate Columns II and III for the smaller sample of firms which are only present in either one of the survey waves, these results are not driven by firms that have been sampled twice.

Of the firm-level controls, only firm age appears to consistently affect the probability of delegation at the 1% level. As far as the province-level controls are concerned, none have coefficients significantly different from zero.

Table 3.6 reports estimates of β and γ in equation (3.3), the probability that the firm contracts out the management of its finances. The marginal effects are given in Table 3.7, Panel B. I use the same specification as in the delegation equations, but the independent variable is now an indicator variable which takes a value of 1 if the firm contracts out financial management.

A greater level of trust (as measured from the WVS) does not increase the probability of contracting out financial management. On the contrary, when trust is instrumented with social capital (Columns II-V), the coefficient on trust is negative, although it is not significant. The relationship between trust and the probability of contracting out the management of firm finances to accountants and auditors also does not appear to be affected by the size of the firm. None of the interactions between trust and size (Column III) is significant. The results are robust to the exclusion of firms that have been sampled twice (Columns VI and V). Larger firms (by employees) are more likely not to manage their own finances than smaller firms: the coefficient on labour is positive and significant at the 1%. Firms with a larger share of white-collar employees, on the other hand, are less likely to do so, which suggests that white-collar employees are qualified to look after the firms' finances. Both effects are significant at the 1% level and robust across all specifications. Neither the other firm-level nor the province-level explanatory variables appear to be drivers of the chances that financial management be contracted out.

I conclude that trust does not appear to significantly affect contracting decisions in my sample.

3.4 Conclusion

This paper has investigated some of the implications of trust on firms' activity. Controlling for various environmental and firm-specific factors, I find that the positive correlation between trust and firm performance that appears in cross-country regressions may be spurious, as using within-country variation I do not find a correlation between trust and the performance of larger firms. If anything, my estimates suggest that a greater level of trust improves the efficiency of smaller firms.

I do not find that trust plays a role in the contracting activities undertaken by firms across different parts of Italy. However, there may not be enough cross-sectional variability in my sample to correctly identify the impact of trust on the decision to hire managers, accountants and auditors. Moreover, I am not able to control for the prices of these services, which ought to be a key driver of these choices.

TABLE 3.1: UNBALANCED PANEL

Number of firms	6,474
Number of firms in 1998 survey	3,995
Number of firms in 2001 survey	3,504
Firms with product innovation	56.24%
Firms with process innovation	60.53%
Firms with product-related organisational innovation	19.76%
Firms with process-related organisational innovation	31.08%
Firms that delocalise production	2.23%
Firms that delegate control	7.89%
Firms that delegate financial management	3.20%
Firm distribution by size	
Small: 0-20 employees	25.84%
Medium: 21-250 employees	43.03%
Large: 251+ employees	29.43%

Notes: See the Appendix for a detailed description of the variables. Percentages expressed out of total number of firms in the pooled sample, except for firms that delocalise, which are expressed out of the number of firms in the 2001 survey.

TABLE 3.2: SUMMARY STATISTICS FOR SELECTED VARIABLES

<i>Reference period 1995-2001</i>	Mean	Median	Standard deviation	Minimum	Maximum	Observations
Sales per employee	229.408	176.100	218.814	7.265	7,259.335	5,013
Capital intensity	66.769	41.217	131.708	0.039	6,839.252	4,068
Investment intensity	22.239	7.479	372.417	0.069	20,945.029	3,932
Number of employees	106.486	28	332.199	7.333	7,660	5,058
Share of executives	0.04	0.02	0.059	0	0.855	2,867
Share of white collar	0.223	0.19	0.152	0	0.981	4,996
Age	24.835	21	18.419	1	312	6,474
Trust other Italians (WVS)	0.658	0.670	0.02	0.609	0.686	6,474
Trust family (WVS)	0.940	0.94	0.016	0.879	1	6,474
Referenda turnout	0.84	0.85	0.061	0.62	0.92	6,474
Blood donations	0.035	0.035	0.021	0	0.105	6,474
Judicial inefficiency	3.229	2.872	0.938	1.441	8.324	6,474
Per capita GDP	16.593	16.886	3.356	8.218	22.581	6,474
Average years of education	7.777	7.720	0.654	5.754	10.292	6,474
Use of checks	0.586	0.625	0.147	0.134	0.810	6,474
Delegation	0.081	0	0.273	0	1	6,294
Financial management	0.032	0	0.177	0	1	6,427

Notes: See the Appendix for a detailed description of the variables. Sales, value added, investment and capital per employee are all measured in thousands of 2010 euros. The trust variables are measured at the regional level. The social capital instruments, as well as judicial inefficiency, are measured at the provincial level. Percentages expressed out of total number of firms in the pooled sample, except for firms that delocalise, which are expressed out of the number of firms in the 2001 survey.

TABLE 3.3: REDUCED FORM REGRESSIONS

	I	II
<i>Log turnout</i>	0.129** (0.0538)	0.118** (0.0541)
<i>Log donations</i>	0.00736* (0.00423)	0.00813** (0.00395)
Log capital intensity	1.68e-05 (0.000335)	-0.000174 (0.000405)
Log labour	0.00502 (0.00550)	0.00307 (0.00396)
Log labour squared	-0.000442 (0.000527)	-0.000235 (0.000297)
Log share of white-collars	0.00108 (0.00106)	0.000820 (0.000943)
Log share of executives	0.000979 (0.000625)	0.00111* (0.000624)
Log age	-0.00462 (0.00303)	-0.00151 (0.00279)
Log age squared	0.000913* (0.000520)	0.000337 (0.000491)
Log judicial inefficiency	0.0693 (0.0688)	0.0600 (0.0689)
Log judicial inefficiency squared	-0.0307 (0.0262)	-0.0274 (0.0260)
Log per capita GDP	0.0363 (0.0247)	0.0382 (0.0254)
Log years of education	-0.0724 (0.0538)	-0.0781 (0.0537)
Log use of checks	0.0115 (0.0167)	0.0112 (0.0176)
Observations	6,406	4,430
R^2	0.525	0.536

Notes: The dependent variable is trust as measured by the WVS. Column I is the reduced form equation associated with the 2SLS estimation of the productivity equation, equation (3.1). Column II is the same as column I but it excludes firms that are present in both waves of the USMF. Both regressions include industry and innovation dummy variables, as well as survey wave and year dummies.

TABLE 3.4: EFFECT OF TRUST ON FIRM PERFORMANCE

	I	II	III	IV	V	VI	VII	VIII
Log capital intensity	0.125*** (0.0120)	0.124*** (0.0114)	0.0115*** (0.0119)	0.124*** (0.0116)	0.121*** (0.0108)	0.136*** (0.0171)	0.137*** (0.0173)	0.143*** (0.0162)
Log labour	-0.219*** (0.0592)	-0.236*** (0.0753)	-0.194*** (0.0690)	-0.159** (0.0685)	-0.192*** (0.0741)	-0.190** (0.0815)	-0.119 (0.0766)	-0.182** (0.0914)
Log labour squared	0.0225*** (0.00562)	0.0247*** (0.00746)	0.0206*** (0.00674)	0.0176*** (0.00675)	0.0197*** (0.00718)	0.0196** (0.00787)	0.0134* (0.00724)	0.0184** (0.00878)
Log share executives	0.0846*** (0.0147)	0.0827*** (0.0198)	0.0813*** (0.0207)	0.0814*** (0.0199)	0.0915*** (0.0193)	0.0847*** (0.0231)	0.0805*** (0.0234)	0.0924*** (0.0255)
Log share of white-collar	0.288*** (0.0231)	0.284*** (0.0228)	0.261*** (0.0216)	0.282*** (0.0229)	0.277*** (0.0202)	0.315*** (0.0277)	0.312*** (0.0280)	0.298*** (0.0293)
Log age	0.247*** (0.0773)	0.255*** (0.0971)	0.238** (0.0988)	0.248** (0.0978)	0.199** (0.0988)	0.195* (0.112)	0.184* (0.112)	0.164 (0.115)
Log age squared	-0.0485*** (0.0111)	-0.0501*** (0.0152)	-0.0454*** (0.0151)	-0.0487*** (0.0154)	-0.0403*** (0.0153)	-0.0426** (0.0182)	-0.0404** (0.0182)	-0.0357* (0.0184)
Log judicial inefficiency	0.805** (0.319)	0.624 (0.451)	0.657 (0.468)	0.644 (0.445)	0.626* (0.347)	0.425 (0.503)	0.434 (0.528)	0.471 (0.442)
Log judicial inefficiency squared	-0.327** (0.120)	-0.230 (0.178)	-0.237 (0.185)	-0.236 (0.176)	-0.226 (0.141)	-0.160 (0.201)	-0.168 (0.208)	-0.174 (0.179)
Log per capita GDP	0.114	-0.132	-0.281	-0.123	0.0165	0.0507	0.0689	0.133

	(0.132)	(0.207)	(0.231)	(0.203)	(0.127)	(0.225)	(0.230)	(0.158)
Log years of education	0.0230	0.526	0.670	0.492	-0.273	0.415	0.405	-0.220
	(0.252)	(0.403)	(0.439)	(0.395)	(0.348)	(0.462)	(0.545)	(0.437)
Log use of checks	0.0282	-0.0981	-0.0716	-0.101	-0.0744	-0.246**	-0.240**	-0.190**
	(0.0700)	(0.116)	(0.129)	(0.116)	(0.0764)	(0.124)	(0.117)	(0.0756)
Log trust	1.240**	4.611**	5.217**	4.494*	1.676	4.644*	4.821	3.651
	(0.533)	(2.239)	(2.400)	(2.378)	(2.482)	(2.526)	(3.466)	(3.932)
Log trust if medium				0.522			0.740	
				(1.661)			(1.553)	
Log trust if large				-1.353			-1.952	
				(1.509)			(2.167)	
Log trust if in the north					-0.00922		0.110	-1.760
					(2.350)		(0.224)	(3.541)
Observations	6,419	6,402	5,753	6,402	5,484	4,427	4,427	3,803
R^2	0.326	0.312	0.356	0.313	0.325	0.333	0.333	0.338

Notes: The dependent variable is (log) labour productivity. See the Appendix for a description of all other variables. All regressions include dummies for whether the firm has carried out product, process, product-related organisational and process-related organisational innovation, as well industry dummies. Calendar year and wave dummies are also included as controls. Column I is estimated with OLS. Column II-VIII are estimated using 2SLS with referendum turnout and blood donations as instruments for trust. Column III reports estimates obtained from the first step of the Olley-Pakes (2006) semi-parametric procedure to correct for capital and labour endogeneity. Column IV includes a full set of interactions between trust and firm size, with small firms being the omitted category. Column V includes a full set of interactions between trust and location, with the south being the omitted category. Finally, columns VI-VIII are the equivalent of columns II, IV and V, but they exclude firms which are sampled in both waves of the survey. The standard errors reported in parentheses are corrected for potential clustering of the residuals at the provincial level. The symbols ***, ** and * mean that the coefficients are statistically different from zero at the 1%, 5% and 10% level, respectively.

TABLE 3.5: EFFECT OF TRUST ON DELEGATION

	I	II	III	IV	V
Trust	0.443 (2.800)	2.188 (4.358)	1.406 (4.460)	-3.643 (5.241)	-4.223 (5.363)
Trust and medium			0.421*** (0.135)		0.338** (0.152)
Trust and large			0.0275 (0.177)		-0.0172 (0.193)
Judicial inefficiency	-0.00131 (0.0330)	-0.000725 (0.0360)	-0.00107 (0.0365)	-0.0186 (0.0433)	-0.0185 (0.0443)
Real sales	7.83e-08 (1.17e-07)	7.30e-08 (1.46e-07)	5.75e-08 (1.55e-07)	7.55e-08 (1.54e-07)	6.86e-08 (1.63e-07)
Labour	-5.39e-05 (9.43e-05)	-5.02e-05 (9.28e-05)	3.72e-05 (8.98e-05)	-2.53e-05 (6.31e-05)	4.55e-05 (8.07e-05)
Age	0.00647*** (0.00134)	0.00648*** (0.00157)	0.00600*** (0.00158)	0.00515*** (0.00185)	0.00480*** (0.00184)
Share of white-collar	0.116 (0.178)	0.116 (0.175)	0.162 (0.183)	0.466** (0.204)	0.510** (0.214)
Share of executives	-0.816 (0.732)	-0.821 (0.631)	-0.860 (0.629)	-0.260 (0.786)	-0.282 (0.778)
Per capita GDP	0.0246 (0.0240)	0.0212 (0.0235)	0.0239 (0.0240)	0.0376 (0.0262)	0.0394 (0.0270)
Years of education	-0.0984 (0.0920)	-0.0812 (0.0851)	-0.0832 (0.0872)	-0.182* (0.0933)	-0.183* (0.0955)
Use of checks	-0.00631 (0.631)	-0.0548 (0.478)	-0.0201 (0.499)	0.223 (0.622)	0.255 (0.644)
Observations	12,123	12,123	12,123	8,557	8,557
Pseudo R-squared	0.0650	0.0650	0.0650	0.0650	0.0650

Notes: The dependent variable is a dummy variable which takes a value of 1 if the main capital owner does not manage the firm. See the Appendix for a detailed description of all other variables. All regressions include industry dummies, calendar year and wave dummies as controls. Column I is the Probit regression for delegation estimated without instrumental variables. Columns II-V are estimated using Probit with referendum turnout and blood donations as instruments for trust. Column III includes a full set of interactions between trust and firm size, with micro firms being the omitted category. Finally, column IV and V are the equivalent of II and III respectively, but they exclude firms which are sampled in both waves of the survey. The symbols ***, ** and * mean that the coefficients are statistically different from zero at the 1%, 5% and 10% level, respectively. All specifications include macro-area, industry, survey-wave and year dummy variables.

TABLE 3.6: EFFECT OF TRUST ON FINANCIAL MANAGEMENT

	I	II	III	IV	V
Trust	0.683 (1.377)	-5.873 (4.735)	-5.501 (4.766)	-5.553 (6.185)	-5.315 (6.164)
Trust and medium			-0.138 (0.109)		-0.124 (0.152)
Trust and large			0.0886 (0.130)		0.0392 (0.170)
Judicial inefficiency	0.0142 (0.0485)	0.0115 (0.0432)	0.00932 (0.0430)	0.0394 (0.0518)	0.0380 (0.0513)
Real sales	1.81e-07 (1.54e-07)	1.97e-07 (1.36e-07)	1.86e-07 (1.36e-07)	1.81e-07 (1.36e-07)	1.74e-07 (1.35e-07)
Labour	0.000196*** (7.35e-05)	0.000184*** (6.96e-05)	0.000151** (6.54e-05)	0.000254*** (7.16e-05)	0.000233*** (7.46e-05)
Age	-0.00207 (0.00163)	-0.00214 (0.00286)	-0.00201 (0.00281)	-0.00692** (0.00277)	-0.00671** (0.00262)
Share of white-collar	-1.013*** (0.214)	-1.020*** (0.259)	-1.034*** (0.258)	-1.144*** (0.317)	-1.154*** (0.312)
Share of executives	0.602 (0.736)	0.619 (0.840)	0.569 (0.842)	0.257 (0.831)	0.229 (0.829)
Per capita GDP	0.0213 (0.0149)	0.0359* (0.0193)	0.0353* (0.0193)	-0.00410 (0.0215)	-0.00401 (0.0213)
Years of education	0.0929 (0.0689)	0.0166 (0.0935)	0.0168 (0.0939)	0.0409 (0.104)	0.0391 (0.103)
Use of checks	0.130 (0.555)	0.304 (0.500)	0.268 (0.506)	0.902 (0.632)	0.867 (0.640)
Observations	12,419	12,419	12,419	8,815	8,815
Pseudo R-Squared	0.0656	0.0656	0.0656	0.0656	0.0656

Notes: The dependent variable is a dummy variable which takes a value of 1 if firm contracts out financial management. See the Appendix for a detailed description of all other variables. All regressions include industry dummies, calendar year and wave dummies as controls. Column I is the Probit regression for delegation estimated without instrumental variables. Columns II-V are estimated using Probit with referendum turnout and blood donations as instruments for trust. Column III includes a full set of interactions between trust and firm size, with micro firms being the omitted category. Finally, column IV and V are the equivalent of II and III respectively, but they exclude firms which are sampled in both waves of the survey. The symbols ***, ** and * mean that the coefficients are statistically different from zero at the 1%, 5% and 10% level, respectively. All specifications include macro-area, industry, survey-wave and year dummy variables.

TABLE 3.7: MARGINAL EFFECTS

Panel A: Delegation of direct control					
	I	II	III	IV	V
Trust	0.0747	0.8671	0.5573	-1.4437	-1.6731
Trust if medium			0.1669		0.1337
Trust if large			0.0109		-0.0068
Judicial inefficiency	-0.0002	-0.0003	-0.0004	-0.0071	-0.0073
Real sales	0	0	0	0	0
Labour	0	0	0	0	0
Age	0.0010	0.0026	0.0024	0.002	0.0019
Share of white-collar	0.0195	0.0460	0.0640	0.1848	0.2021
Share of executives	-0.1375	-0.3255	-0.3406	-0.103	-0.1116
Per capita GDP	0.0042	0.0084	0.0095	0.0149	0.0156
Years of education	-0.0166	-0.0322	-0.0330	-0.0722	-0.0724
Use of checks	-0.0010	-0.0217	-0.008	0.0884	0.1011
Panel B: Financial management					
	I	II	III	IV	V
Trust	.0450	-2.3412	-2.1928	-2.2132	-2.1185
Trust if medium			-0.0549		-0.0494
Trust if large			0.0353		0.0156
Judicial inefficiency	0.0009	0.0046	0.0037	0.0157	0.0152
Real sales	0	0	0	0	0
Labour	0	0	0	0	0
Age	-0.0010	-0.0009	-0.0008	-0.0028	-0.0027
Share of white-collar	0.067	-0.4065	-0.4129	-0.456	-0.4599
Share of executives	0.0398	0.2466	0.2264	0.1023	0.0915
Per capita GDP	0.0014	0.0143	0.0141	-0.0016	-0.0016
Years of education	0.0061	0.0066	0.0067	0.0163	0.0156
Use of checks	0.0086	0.1213	0.1069	0.3594	0.3456

Notes: Panel A reports the marginal effects corresponding to the coefficient estimates in Table 3.5, computed at the mean value of the co-variates. Panel B reports the marginal effects corresponding to the coefficient estimates in Table 3.6, computed at the mean value of the co-variates.

3.5 Appendix

3.5.1 Description of the variables

Labour productivity. This is given by real sales, measured in thousands of 2010 euros, over the number of employees. Source: USMF.

Real sales. Nominal sales in thousands of euros deflated using the Italian CPI (2010 = 100). Source: USMF and OECD.

Labour. Number of employees. Source: USMF.

Capital intensity. This is given by firm capital, measured in thousands of 2010 euros, over the number of employees. Firm capital includes land, machinery, buildings and the like. Source: USMF.

Investment intensity. This is given by firm capital investment, measured in thousands of 2010 euros, over the number of employees. Firm capital includes land, machinery, buildings and the like. Source: USMF.

Share of white-collars. Number of white-collar employees over total employees. Source: USMF.

Share of executives. Number of executives over total employees. Source: USMF.

Age. Number of years between the survey year and the year of foundation of the firm. Source: USMF.

Judicial inefficiency. Mean number of years to complete a first-degree trial by the courts located in a province. It has been computed using court-level data on the length of trials and then averaging out across courts located in the same province. Source: GSZ.

Per capita GDP. Real GDP measured in thousands of 2010 euros, over the number of inhabitants of the province as per the 2001 census. Source: Unioncamere and OECD.

Years of education. Average number of schooling years calculated at the provincial level in 1981. Source: GSZ.

Use of checks. Percentage of households sampled by the Bank of Italy's Survey of Household Income and Wealth (pooling the waves of 1989, 1991, 1993, and 1995) that use checks in a province. Source: GSZ.

Trust. An index of the level of trust based on the WVS for Italy run among 2,000 individuals in years 1989 and 1999. The WVS contains the question "Using the responses on this card, could you tell me how much you trust Italian people in general? (1) Trust completely (2) Trust a little (3) Neither trust or distrust (4) Not trust very much (5) Not trust at all". I recoded the responses in the reverse order, I constructed an index for each survey and then I averaged the two indices. Source:

WVS.

Turnout. Voter turnout at the province level for all the referenda before 1989. The relevant period is 1946-1987. For each province turnout data were averaged across time. Source: GSZ.

Donations. Number of blood bags (each bag contains 16 ounces of blood) per million inhabitants in the province collected by AVIS, the Italian association of blood donors, in 1995 among its members. Source: GSZ.

Medium. A categorical variable which is equal to 1 if a firm reports a number of employees in the interval [51, 250]. Source: elaboration based on USMF.

Large. A categorical variable which is equal to 1 if a firm reports a number of employees larger than 251. Source: elaboration based on USMF.

Delegates. A categorical variable which is equal to 1 if the main capital holder of the firm does not retain “direct control” of the firm. Source: USMF.

Contracts out management of own finances. A categorical variable which is equal to 1 if the firm contracts out the management of its own finances.

North. A categorical variable which is equal to 1 if the province of registration of the firm is north of Florence. Source: GSZ.

South. A categorical variable which is equal to 1 if the province of registration of the firm is south of Rome. Source: GSZ.

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