

Government Information Transparency*

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Abstract

This paper studies a model of announcements by a privately informed government about the future state of economic activity in an economy subject to recurrent shocks and with distortions due to income taxation chosen by majority voting. Although transparent communication would ex-ante be desirable, we find that even a benevolent government may decide to be non-informative in an attempt to countervail the tax distortion in a second-best type of policy. In a politico-economic (Nash) equilibrium, transparency critically depends on inequality, which influences both tax and information distortions. Such influence in turn depends on labor supply elasticity. Our results provide a rationale for independent national statistical offices, committed to truthful communication.

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1 Introduction

Many governments are better informed than the private sector about future realizations of macroeconomic variables. Often they transparently convey this information to the public, but on other times they do not. For instance, the US government's announcements on current or future activity have a positive real effect on the economy, confirming the fact that individuals find them informative (Oh and Waldman, 1990; Rodríguez Mora and Schulstald, 2007).¹ But the widespread skepticism on contemporary Argentinean official statistics provides an example of non transparent and non credible government announcements. While there may be different opportunistic reasons for governments not to be transparent, in the present paper we investigate whether a benevolent government should always reveal its private information on real macroeconomic variables. For the sake of concreteness, we focus on the case in which the government has prior information on exogenous aggregate productivity shocks that produce uniform positive (in booms) or negative (in recessions) shifts in individual productivities. Should the government always fully reveal this information? Is it efficient to do so? Are there circumstances in which it is welfare efficient not to disclose information?

In an otherwise perfectly competitive, first best economy a benevolent government would always reveal its private information. But consider a second best world, in which there are unavoidable distortions. Then by appropriately distorting information communication, a benevolent government might hope to increase social welfare. For instance, suppose that income taxes make labor supply sub-optimal. Then if the government knows that the economy is hitting a recession and does not reveal such information, it may hope that the increase in labor supply caused by ignorance compensates the under-supply of labor caused by taxation.

Indeed, if individuals mechanically believe its announcements (if they are credulous), the government may even be able to restore the first best outcome through an appropriately over-optimistic communication strategy. Yet, with rational individuals, misleading information about a recession will make the government lose credibility. In particular, when the economy is hitting a boom and the government announces it, individuals will discount such announcement. This, in turn, further worsens the under-supply of labor in booms, and thus reduces social welfare in good times. In recessions,

¹Interestingly, such announcements are believed even when based on false information.

by hiding information, the government raises labor supply, relative to what it would be under perfect information, so that it may (at least partially) compensate for the welfare loss caused by taxation. Yet, it may also raise labor supply so much, that it indeed causes an over-supply of labor (relative to the first best), whose welfare costs are higher than those due to taxation under perfect information. The higher the tax distortion, the less likely it is that this happens. Thus, roughly, the higher the tax distortion, the higher the incentive to hide negative information. In this framework, we investigate the emergence of informative and non-informative government communication regimes. In particular, concerning transparency we obtain the following results: (1) there are equilibria in which a benevolent government chooses an informational policy consisting in being optimistic in recessions, (2) whether the equilibrium policy consists of telling the truth or misinforming depends of the magnitude of the productivity shocks relative to the distortion caused by income taxation, and (3) the range of tax rates for which transparency is the equilibrium strategy broadens or shrinks with inequality depending on whether labor supply is rigid or elastic.

We also find that transparency (i.e., information revelation) is desirable *ex ante*, but *ex post* it may turn out not to be feasible, because even a benevolent government may want to hide negative information. The policy implication is then straightforward: when distortions are substantial in magnitude and difficult to remove, the government should find some commitment device to transparency. For instance, announcements over the economic outlook might be delegated to an independent statistical office committed to transparency.²

Formally, we represent the government's announcement game as a cheap talk game (Crawford and Sobel, 1982) with multiple and heterogenous receivers. We characterize its equilibria and find that non informative equilibria always exist, whereas an informative equilibrium exists if and only if tax distortions are relatively small.³ In non informative equilibria, government

²Our work is but a first step in studying the role of announcements made by the government. We focus on the case where the shocks are purely exogenous and out of the government's control. In many interesting cases, the direction and size of the shock depend on actions taken by the government. This clearly is the case of many monetary and fiscal policies influencing the real economy. In this case, the informational policy has to be jointly modeled with the other instruments in the hands of the government. This line of research remains open.

³We also characterize a possible partially informative equilibrium, in which the government's announcements are over-optimistic in recessions.

announcements convey no information. In an informative equilibrium, the government is transparent (i.e., its announcements fully reveal its private information) and credible (in the sense that, if announcements have a literal meaning, this naturally coincides with their equilibrium interpretation). An appropriate equilibrium refinement uniquely selects the informative equilibrium whenever it exists, so that our comparative statics is conducted on the tax distortion threshold, below which it exists.

We finally complete the model by obtaining the tax rate that would result from majority voting (Meltzer and Richard, 1981). We examine the existence and properties of the *politico-economic* equilibria such that the information policies and the majoritarian tax rates are mutually consistent. We obtain that the ideal tax rate is strictly decreasing in income and that preferences over tax rates are single peaked. It follows that the pivotal voter for a majority is the individual with the median productivity. We show that if the elasticity of labor supply is less than unity [the empirically most relevant case] the endogeneization of the choice of the tax rate makes the condition for transparency even tighter as far as inequality is concerned. An increase in the gap between the mean and the median productivity induces the median voter to prefer a higher tax rate and hence eventually violate the condition for transparent policies. When the elasticity of labor supply is high the condition for transparency loosens.

Our analysis is related to a number of literatures and open discussions. First of all, transparency and provision of accurate information have indeed been very prominent in recent debates on institutional and policy reforms; to the point of becoming a typical leitmotif in the discussions. For example, the Federal Open Market Committee (FOMC) announced in November 2007 that, consistently with greater commitment to improving accountability, it will increase the frequency and expand the content of the economic projections released to the public.⁴ In other countries, central banks and Statistics Offices have adopted a range of methods aiming at improving their communication.⁵

⁴Projections on consumption will be included for the first time together with forecast on gross domestic product (GDP) growth, the unemployment rate, and inflation. In addition, the projection horizon will be extended to three years, from two.

⁵These include timely announcements of policy actions, frequent public speeches a meetings with legislature, and the regular publication of reports about the real economy and monetary policy. The Reserve Bank of New Zealand and the Bank of England were early and enthusiastic leaders in this process towards greater transparency, together with the

The policy emphasis on transparency and credibility has been accompanied by a huge economic literature, which, at least since Kydland and Prescott (1977), has mostly focused on their importance for central banks (a recent assessment can be found in Blinder et al., 2008).⁶ Much of these contributions emphasize monetary channels and assume private information on policy goals.⁷ Two prominent examples, among others, are Cukierman and Meltzer (1986) and Stein (1989).⁸ We differ from this line of research in that we emphasize real rather than monetary channels and assume private information about macroeconomic outlook rather than about policy goals. As argued above, both aspects appear to be relevant and worth of analysis.⁹

A recent and important strand of the literature looks at how economic policy depends on transparency and informational asymmetries, finding that

Norges Bank (the central bank of Norway) and Sveriges Riksbank (the central bank of Sweden). Finally, The European Central Bank has adopted a fully transparent communication strategy since it was created in 1998. Geraats (2009) shows that there has been a notable increase in economic transparency between 1998 and 2002, although the intensity varied across countries.

⁶In Faust and Svensson (2001) transparency takes the form of making public announcements more precise. Governments are credible if their announcements are believed to be true. Transparency builds credibility and, as a consequence, it has become an ingredient of the common wisdom of policy making (Faust and Svensson, 2002). This consensus is absolute among central bank authorities. As reported by Blinder (2000), central bankers consider transparency a “fine way to build credibility”. Interestingly, when asked the same questions, non-central bank economists are not that enthusiastic about the importance of transparency.

⁷A smaller literature (see, e.g., Sleet, 2001) posits private government information about productivity shocks, as we do here, and investigates its consequences for time consistency of optimal monetary policy. It should be stressed that we do not deal with monetary policy and that credibility in our model does not mean time consistency. Rather, it means that in equilibrium different announcements receive different meanings (so that the natural and the equilibrium meaning of government announcements may coincide).

⁸The former paper investigates the central bank’s incentive to maintain ambiguous procedures of monetary control, in order to be able to surprise rational agents whenever its policy goals shift. The latter uses a cheap talk framework to emphasize the central bank’s incentive to make imprecise announcements about its goals, exactly because precise announcements would induce it to lie (in order to manipulate expectations).

⁹The fact that central authorities have an informational advantage over the private sector has been widely documented and it has been mainly attributed to the fact that they devote substantially more resources to forecasting than private forecasters, and possibly also use better forecasting methods (Romer and Romer, 2000; Kurz, 2005; Kohn and Sack, 2004; Athey et al., 2005). The fact that central authorities’ announcements influence private behavior is also well documented (Oh and Waldman, 1990, 2005; Blinder et al., 2008).

transparency may generate economic distortions. We tackle the complementary question and show how transparency is endogenously determined by pre-existing distortions.¹⁰

While an interesting literature investigates the government's opportunistic incentives to distort the economy in one way or another, we have nothing to add to it. Rather, we investigate the complementary question of why a benevolent government would impose further distortions to an already distorted economy. We are thus closer to the literature on second best, in the sense that in our model it is precisely the existence of a first distortion what disrupts transparency and credibility. In particular, the mechanism we explore is related to the idea that random taxes may raise welfare, compared to certain taxes, because randomness may reduce the deadweight loss associated to income taxes.¹¹ The main difference is that in our case uncertainty is not associated to random tax rates, but rather to uninformative announcements.

We do not investigate here any reputational incentives for transparency. Yet, the literature on the topic (e.g., Morris, 2001; Ottaviani and Sorensen, 2006) finds that in many cases reputation provides an incentive to hide rather than to reveal information.

A recent line of research investigates the interaction between the disclosure of noisy public information and the use (and quality) of private information. In an influential paper, Morris and Shin (2002) show that noisy public information, if used to coordinate actions, may lead individuals to disregard alternative valuable private information.¹² More recently, Amador and Weill (2008) emphasize that releasing public information would jeopardize

¹⁰Several papers are concerned by the political economy of budget deficits and find that higher transparency reduces public debt (Milesi-Ferreti, 2004; Shi and Svensson, 2006). More recently, Gavazza and Lizzeri (2009a,b) concentrate on the effects of different types of transparency in presence of political competition, where voters are misinformed about aggregate government spending and either revenues (Gavazza and Lizzeri, 2009b) or the incumbent government's ability (Gavazza and Lizzeri, 2009a). These papers show that although transparency of spending is beneficial, higher transparency of either revenues or incumbent's ability may lead to wasteful spending and higher public debt. See also Barigozzi and Villeneuve (2006), where taxes have a signaling value.

¹¹Weiss (1976) shows this result under the assumption, that we maintain, that utility is separable in consumption and leisure. See Arnott and Stiglitz (1988) and Sleet (2004), among others, for extensions of this literature.

¹²This reasoning has been used to warn against Central Bank transparency (Amato et al., 2002). Interestingly, Svensson (2006) argues that the result of Morris and Shin (2002) suggests that transparency increases welfare when public information is more precise than private information. We find an analogous result.

dize the price system ability to aggregate and transmit private information, which could result in welfare losses. We differ from this literature because, rather than investigating the interaction between public and private information, we study how public information disclosure depends on pre-existing distortions. In this sense, our paper is more related to Angeletos and Pavan (2009), who investigate the complementary question of how optimal taxation should take into account the information structure.¹³

Our theory builds on the cheap-talk literature. Farrell and Gibbons (1989) extend the standard cheap-talk game (Crawford and Sobel, 1982) to two audiences and, restricting attention to two states and two actions, discuss the difference between private and public communication. We differ from their analysis because, while we also restrict to two states, but only focus on public communication, we consider a continuum of heterogeneous receivers, each with a continuum of actions. This framework is more suitable to investigate public messages addressed to an entire population, beyond our specific model. Moreover, our analysis also yields some insights of technical interest for game theorists, since it shows that some of the results obtained for the two-audience and two-action case do not generalize.¹⁴

A main contribution of our paper is to reveal a connection between inequality and transparency. In this sense, our work also relates to the literature on the effects of inequality on resource allocation (and growth).¹⁵ An important message of this literature is that in the presence of distortions (capital market imperfections in most papers) inequality aggravates the misallocation of resources. In our case too, an existing distortion such as income taxation induces a benevolent government to create an additional (compensating) distortion in the transmission of information. The magnitude of this second source of inefficiency depends of the degree of inequality. This result is in line with Esteban and Ray (2006) where the misallocation of resources created by an efficiency seeking government positively depends on the degree of inequality.

¹³They propose a tax scheme that guarantees that individuals make a better use of both private and public information with the additional effect that the provision of public signal would increase welfare.

¹⁴Farrell and Gibbons (1989) show that in what they call a ‘coherent’ game, the sender prefers separating to pooling, ex post and therefore also ex ante. This is not true in our model, although, for a natural extension of their definition of ‘coherence’, our game is also coherent. Indeed, their argument critically depends on the two-action assumption.

¹⁵See the survey by Bénabou (1996).

The remainder of this paper is organized as follows. Section 2 displays the government's announcement game and the determination of tax rates by majority voting. Section 3 characterizes the equilibria of the announcements game and studies their properties. Section 4 investigates the politico-economic equilibria. Section 5 discusses the main implications of our results and Section 6 concludes. In Appendix we derive a technical result and develop two examples.

2 The model

2.1 The economy

There is a mass one of individuals, who have the same preferences but differ in productivity. Utility depends on consumption and labor: $u(c, \ell) = c - \frac{\ell^\delta}{\delta}$. The parameter $\delta > 1$ captures the degree of convexity of labor supply, which is linear in the wage for $\delta = 2$, strictly convex for $\delta \in (1, 2)$ and strictly concave for $\delta > 2$.

Individuals earn competitive wages, so that labor income y (equivalently, production, taken as numeraire) is simply equal to individual supply of efficiency units of labor. Individual productivity depends on two factors: an idiosyncratic observable component (ability or human capital), denoted β and distributed according to the cumulative distribution function F , with support on the non empty interval $[b, B) \subset \mathbb{R}_+$; and an aggregate ex-ante unobservable component (say, being in a boom or in recession), denoted θ and distributed according to

$$\theta = \begin{cases} \vartheta & , \text{ with probability } p \\ -\vartheta & , \text{ with probability } (1 - p) \end{cases} ,$$

with $p \in (0, 1)$. We assume $\vartheta \in (0, b)$ to assure that individual productivity is always positive.

Individual labor income therefore depends on effort, ability and aggregate conditions, $y_\beta = (\beta + \theta)\ell_\beta$. Labor income is taxed at a constant marginal rate $t \in (0, 1)$ and tax revenues $T = \int_b^B ty_\beta dF(\beta)$ are equally redistributed, so that individual consumption is equal to $c_\beta = (1 - t)y_\beta + T$. Since the population is continuous, each individual takes T as given.¹⁶ We momentarily

¹⁶The tax collection per capita T will depend on the realization of θ . Therefore, individuals

take t as given. In Section 4 we study the choice of taxation by majority voting.

From our assumption on preferences it is immediate to obtain that, if individuals could observe the realization of θ before choosing their effort level, they would choose $\ell_\beta = [(1-t)(\beta+\theta)]^{\frac{1}{\delta-1}}$ and produce $y_\beta = (1-t)^{\frac{1}{\delta-1}}(\beta+\theta)^{\frac{\delta}{\delta-1}}$. Taxes impose a downward distortion in individual effort supply, relative to the social optimum, which would require $\ell_\beta = (\beta+\theta)^{\frac{1}{\delta-1}}$.

2.2 The Announcements Game

We investigate what happens when individuals are not perfectly informed on the true value of θ , but have to decide on the basis of beliefs, which in turn may be influenced by government's announcements. Specifically, we assume that information is as follows. First Nature draws θ from the above distribution. Both F and the distribution of θ are common knowledge. The government observes the realization of θ and then chooses a (payoff irrelevant) message m from a set of feasible messages $M = \{L, H\}$. Individuals observe m , but not θ , and then simultaneously choose their labor effort to maximise utility. Ex-post the realization of θ is observed by all individuals, who are paid accordingly. The aim of the government is to maximise social welfare $W = \int_b^B u_\beta dF(\beta)$, where u_β denotes the utility of an individual with ability β and depends on t , on θ , on individual labor effort ℓ_β , and on the labor effort chosen by the entire population (since T depends on it).

To fix ideas, in this (cheap talk) signaling game an equilibrium consists of three items:

[1] Individuals map any possible signal the government might send into posterior beliefs about the probability of a boom. Call these posterior beliefs $\mu = \Pr(\theta = \vartheta | m = L)$ and $\nu = \Pr(\theta = \vartheta | m = H)$. Along the equilibrium path of play μ and ν must be obtained from the government's announcement strategy through Bayes' Rule. We assume that out of equilibrium beliefs are the same for everybody.

[2] Given posterior beliefs, individuals map received signals into effort levels $\ell_\beta(m)$, so as to best respond to the government's announcement (and, although this is immaterial, to everybody else choosing the same strategy).

will entertain conjectures about their value. As we shall see, because of our assumption on individual preferences these conjectures are immaterial because they have no effect on labor supply.

[3] The government maps the observed realizations of the shock into signals $m(\theta)$. The government's strategy is a best response (i.e., it maximizes social welfare), given individual labor supply strategies.

Note that since m is payoff irrelevant, there can only be two types of pure strategy (weak perfect Bayesian) equilibria: a pooling one and a separating one. Without loss of generality, let the government choose $m(\vartheta) = m(-\vartheta) = H$ at a pooling equilibrium and $m(\vartheta) = H$ and $m(-\vartheta) = L$ at a separating equilibrium. When allowing for mixed strategies, let ρ and σ denote the probability with which the government sends signal H in recessions and in booms, respectively: $\rho = \Pr(m(-\vartheta) = H)$ and $\sigma = \Pr(m(\vartheta) = H)$.¹⁷

2.3 Voting over Taxes

We have taken the tax rates as given. In order to endogenize taxes we assume that the tax rate is chosen by majority voting along the lines of Romer (1975), Roberts (1977) and Meltzer and Richard (1981). Implicitly in this standard voting model there are two political parties that have to choose a tax rate garnering a majoritarian support. The proposed tax rate critically depends on the preferences of the pivotal voter.

Our model satisfies the sufficient conditions for the pivotal voter to be the individual with the median income. Indeed, as we shall see, individual preferences over taxes are single peaked and the ideal tax rate is strictly decreasing with the known productivity parameter β .

Notice, however, that in our model there are two possible regimes, depending on whether or not the government transmits truthful information. Under a fully informative policy individuals will face fluctuating—but known—wages, while with an uninformative policy individuals will find themselves in a stationary situation with wage uncertainty. The preferred taxes under the two scenarios will be different.

A *Politico-Economic Equilibrium* is an informational policy and a tax rate such that, given the informational policy, this tax rate is the one preferred by the median voter and, given this tax rate, that informational policy is an equilibrium of the announcements game.

¹⁷As it will become clear in section 3, an equilibrium is non-informative when $\rho = \sigma$; informative, or, equivalently, transparent, when $\rho = 0$ and $\sigma = 1$; and partially informative when $(\sigma - \rho) \in (0, 1)$.

3 Equilibrium of the Announcements Game

3.1 Existence

We first establish existence and characterize the set of all equilibria of the cheap talk game. Besides the omnipresent babbling equilibria, we prove that pooling, separating and semi-separating equilibria exist. We provide a closed form expression of a tax threshold that determines their existence. We use this threshold for conducting comparative statics on the effects of the magnitude of shocks and inequality. For some parameter values multiple equilibria exist. In these cases, we show that appropriate equilibrium refinements select the separating equilibrium whenever it exists. Interestingly, we prove that pooling equilibria (i.e. non-informative government communication regimes) emerge in equilibrium whenever the tax distortions are sufficiently high.

As mentioned above, let $\rho = \Pr(m(-\vartheta) = H)$ and $\sigma = \Pr(m(\vartheta) = H)$ describe the government's (mixed) strategy; let $\mu = \Pr(\theta = \vartheta|m = L)$ and $\nu = \Pr(\theta = \vartheta|m = H)$ describe individual posterior beliefs; and let $E(\theta|L) = \mu\vartheta - (1 - \mu)\vartheta = (2\mu - 1)\vartheta$ and $E(\theta|H) = \nu\vartheta - (1 - \nu)\vartheta = (2\nu - 1)\vartheta$ denote the expected value of the aggregate shock, when expectations are based on posterior beliefs.

Lemma 1 (Labour supply)

Given posterior beliefs, individuals' best response to government's announcements is described by the following labor supply strategy:

$$\ell_{\beta}^*(m) = \{(1 - t) [\beta + E(\theta|m)]\}^{\frac{1}{\delta-1}}. \quad (1)$$

Proof $\ell_{\beta}^*(m) = \operatorname{argmax}_{\ell} [(1 - t) [\beta + E(\theta|m)] \ell + E(T|m) - \frac{1}{\delta} \ell^{\delta}]$.¹⁸ ■

Lemma 1 establishes that individuals base labor supply choices on expected net wage, with an elasticity equal to $\gamma \equiv \frac{1}{\delta-1}$. Notice that most microeconomic estimates suggest a value of γ between zero and one, implying $\delta \geq 2$.

¹⁸Notice that $E(T|m)$ is immaterial to individual choices, since individuals take it as given. Therefore its precise definition will be given later.

Let us first consider babbling equilibria. A babbling equilibrium is an equilibrium in which individual labor supply strategies disregard the government's announcement, and the government's signalling strategy disregards the realization of the shock.

Proposition 1 (Babbling equilibria)

For any $\xi \in [0, 1]$, there exists a unique babbling equilibrium, in which $\rho = \sigma = \xi$ and $\mu = \nu = p$.

Proof From Lemma 1, given $\mu = \nu = p$, individual optimal labor supply is $\ell_\beta^*(L) = \ell_\beta^*(H)$, irrespective of the government's announcement, so that, whatever the realization of θ , the government is indifferent between L and H , since social welfare does not depend on the announcement. In particular, $\forall \xi \in [0, 1]$, mixing with the same probability ξ in booms and in recessions is a best response to $\ell_\beta^*(m)$. Given $\rho = \sigma = \xi$, in turn, individuals do not learn anything from government's announcements, so that $\mu = \nu = p$ follows from $\rho = \sigma = \xi$ via Bayes' rule if $\xi \in (0, 1)$; if $\xi \in \{0, 1\}$, then the same is true for either μ or ν , whereas no restriction is placed on out of equilibrium beliefs, so that in particular we can have $\mu = \nu = p$. ■

This characterizes the set of all babbling equilibria.

Remark 1 *All babbling equilibria are equivalent in terms of equilibrium outcome of labor supply, consumption, utility and social welfare.*

Remark 2 *No other equilibria exist with $\mu = \nu$, apart from babbling ones, since optimal labor supply is defined in Lemma 1 and any government's strategy with $\rho \neq \sigma$ would imply, through Bayesian updating, $\mu \neq \nu$.*

We now examine non babbling equilibria, in which it must be the case that $\mu \neq \nu$.

Lemma 2 (Announcement in booms)

Given posterior beliefs, let individual labor supply strategies be defined by (1). In booms, the government's best response is to announce H if and only if $\nu \geq \mu$.

Proof If $\theta = \vartheta$ (i.e., in booms), social welfare is maximum when an individual with ability β chooses an effort level $(\beta + \vartheta)$. Taxes and uncertainty on

θ make labor supply (1) suboptimally low, so the government's best response is to make the announcement that induces the highest expected value of θ , and therefore the highest level of labor supply. ■

It is therefore without loss of generality to let H be the signal sent in booms in any non babbling equilibrium, and therefore focus on $\mu < \nu$. To study the government's best response in recessions, it is convenient to rewrite (1) as $\ell_\beta^*(L) = (1-t)^{\frac{1}{\delta-1}}x_\mu$ and $\ell_\beta^*(H) = (1-t)^{\frac{1}{\delta-1}}x_\nu$, so that

$$\begin{aligned} x_\mu &= [\beta + E(\theta|L)]^{\frac{1}{\delta-1}} = [\beta + (2\mu - 1)\vartheta]^{\frac{1}{\delta-1}}, \\ x_\nu &= [\beta + E(\theta|H)]^{\frac{1}{\delta-1}} = [\beta + (2\nu - 1)\vartheta]^{\frac{1}{\delta-1}} \end{aligned}$$

capture the effect of gross expected salary (equivalently, expected productivity) on labor supply, when posterior beliefs are μ and ν , respectively. Government's behavior in recessions depends on whether social welfare is higher upon announcing L or H . The essence of this welfare comparison is captured by a decreasing (for $\mu < \nu$) function of t ,

$$Z(t) = \frac{1-t}{\delta} \int_b^B (x_\nu^\delta - x_\mu^\delta) dF(\beta) - \int_b^B (\beta - \vartheta)(x_\nu - x_\mu) dF(\beta), \quad (2)$$

whose first and second term reflect welfare differences due to leisure and to consumption, respectively. Government's announcements in recessions will then be discriminated by the following threshold (defined for $\mu \neq \nu$, but which we need to consider only for $\mu < \nu$):

$$t^*(\mu, \nu) = 1 - \frac{\int_b^B (\beta - \vartheta)(x_\nu - x_\mu) dF(\beta)}{\int_b^B \frac{1}{\delta}(x_\nu^\delta - x_\mu^\delta) dF(\beta)}. \quad (3)$$

In Lemma 5 in Appendix B we prove analytically that $t^*(\mu, \nu)$ is strictly increasing in its arguments (in the range of μ and ν such that $0 \leq \mu < \nu \leq 1$) for $\delta = 1.5$ and $\delta = 2$ (and for any skill distribution with finite mean and variance). In Appendix C we show numerically that this result generalizes to many other parameter values and distributional assumptions.

Lemma 3 (Announcement in recessions)

Given posterior beliefs $\mu < \nu$, let individual labor supply strategies be defined by (1). Then $t^(\mu, \nu) \in (0, 1)$. In recessions, the government's best response*

is to announce L if $t < t^*(\mu, \nu)$; to announce H if $t > t^*(\mu, \nu)$; and to choose any $\rho \in [0, 1]$ if $t = t^*(\mu, \nu)$.

Proof Let $u_\beta^*(m|\theta)$ denote the utility gained by an individual with ability β when the government announces m , the true state of the world is θ , and individual strategies are described by (1), given $\mu < \nu$. If $\theta = -\vartheta$ (i.e., in recessions), we have

$$\begin{aligned} u_\beta^*(L|-\vartheta) &= (1-t)(\beta-\vartheta)(1-t)^{\frac{1}{\delta-1}}x_\mu + T^*(L|-\vartheta) - \frac{1}{\delta} \left[(1-t)^{\frac{1}{\delta-1}}x_\mu \right]^\delta, \\ u_\beta^*(H|-\vartheta) &= (1-t)(\beta-\vartheta)(1-t)^{\frac{1}{\delta-1}}x_\nu + T^*(H|-\vartheta) - \frac{1}{\delta} \left[(1-t)^{\frac{1}{\delta-1}}x_\nu \right]^\delta, \\ T^*(L|-\vartheta) &= t \int_b^B (\beta-\vartheta)(1-t)^{\frac{1}{\delta-1}}x_\mu dF(\beta), \\ T^*(H|-\vartheta) &= t \int_b^B (\beta-\vartheta)(1-t)^{\frac{1}{\delta-1}}x_\nu dF(\beta). \end{aligned}$$

The welfare difference between announcing L and H can be written as

$$\begin{aligned} \Delta W &\equiv W(L, \ell^*|-\vartheta) - W(H, \ell^*|-\vartheta) = \\ &= \int_b^B [u_\beta^*(L|-\vartheta) - u_\beta^*(H|-\vartheta)] dF(\beta) = \\ &= (1-t)^{\frac{1}{\delta-1}} Z(t). \end{aligned}$$

For $t = 1$, work effort is zero for any pair of posterior beliefs and we have $\Delta W = 0$. For $t < 1$, the sign of ΔW is equal to the sign of $Z(t)$. $Z(t)$ is a continuous function, strictly decreasing in t and with $Z(1) < 0$. We now prove that $Z(0) > 0$. Given $\mu < \nu$, we have $x_\mu < x_\nu$, so we can write

$$Z(0) = \int_b^B (x_\nu - x_\mu) \left[\frac{x_\nu^\delta - x_\mu^\delta}{\delta(x_\nu - x_\mu)} - (\beta - \vartheta) \right] dF(\beta),$$

Consider now the function $\frac{x^\delta}{\delta}$. For $\delta > 1$, it is convex and hence

$$x_\mu^{\delta-1} < \frac{x_\nu^\delta - x_\mu^\delta}{\delta(x_\nu - x_\mu)} < x_\nu^{\delta-1}.$$

From the first inequality, recalling that $x_\mu^{\delta-1} = (\beta - \vartheta + 2\mu\vartheta)$, we have $\left[\frac{x_\nu^\delta - x_\mu^\delta}{\delta(x_\nu - x_\mu)} - (\beta - \vartheta) \right] > 2\mu\vartheta$, so that

$$Z(0) > 2\mu\vartheta \int_b^B (x_\nu - x_\mu) dF(\beta) > 0.$$

Hence, $\forall(\mu, \nu) : 0 \leq \mu < \nu \leq 1$, there is a unique value of $t \in (0, 1)$, which we call $t^*(\mu, \nu)$, such that $Z(t^*(\mu, \nu)) = 0$. Explicit calculation yields (3). Hence, in recessions, for $t \in (0, t^*(\mu, \nu))$, $\Delta W > 0$ and the government strictly prefers to announce L ; for $t = t^*(\mu, \nu)$, $\Delta W = 0$ and the government is indifferent between the two signals, so that any randomization is a best response; and for $t \in (t^*(\mu, \nu), 1)$, $\Delta W < 0$ and the government strictly prefers to announce H . ■

The proof of Lemma 3 highlights the interaction between the tax distortion and the information distortion induced by the government if it does not fully reveal private information that the economy is hitting a recession. Given that the true state is a recession and for given beliefs, the relative welfare advantage of announcing a recession (over cheating and announcing a boom) can be expressed as $\Delta W = (1 - t)^{\frac{1}{\delta-1}} Z(t)$, i.e., as the product of two effects. Let us consider them in turn.

$Z(t)$ captures the fact that, given the way in which individuals map announcements to beliefs, the government, by cheating and announcing a boom, is able to raise individual expectations on wages, and therefore to stimulate labor supply. When taxes are zero, this is inefficient, since it induces workers to supply effort in excess of what is optimal. Consider now an increase in taxes. Whatever the announcement, the tax increase reduces labor supply. If the government reveals information, then, it induces a suboptimal level of labor supply. Thus, upon revelation of information, labor supply falls the further below from the social optimum the higher the taxes. In contrast, with higher taxes, cheating induces a smaller amount of overwork. As taxes increase, the overwork induced by cheating gets lower and lower. At the beginning this effect is small, so that, for low taxes, namely for $t < t^*(\mu, \nu)$, the government still prefers to reveal information. When taxes are $t = t^*(\mu, \nu)$, the welfare cost of the overwork induced by cheating is exactly equal to the welfare cost of underwork induced by revelation, so that the government is indifferent. As taxes further increase above $t^*(\mu, \nu)$, the overwork induced by cheating first goes to zero and then eventually becomes underwork. At any rate, for $t > t^*(\mu, \nu)$ work supply is closer to the social optimum if the government cheats than if it reveals information about a recession.

The effect of $Z(t)$ is scaled by $(1-t)^{\frac{1}{\delta-1}}$. This term captures the fact that, by reducing labor supply after any announcement, taxes also reduce the welfare difference between revealing and hiding information. Eventually, as t approaches 1, labor supply converges to zero whatever the announcement, and the welfare difference between revealing and hiding information completely vanishes. Figure 1 plots ΔW against t for different values of ν , given $\mu = 0, \vartheta = 0.5, \delta = 3$ and a Pareto distribution of β with scale parameter $b = 1$, i.e., with support on $[b, B) = [1, \infty)$, and shape parameter $\alpha = 3$. The qualitative pattern is analogous for different parametric and distributional assumptions.

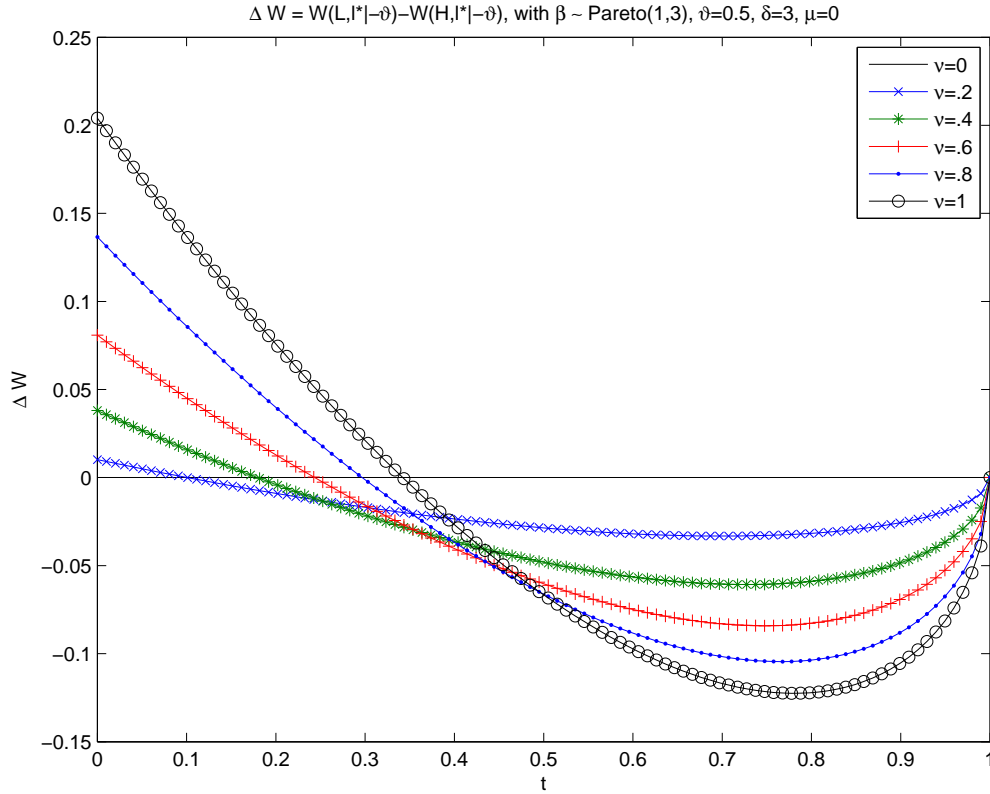


Figure 1: The incentive to reveal information on a recession as a function of tax distortion, for $\mu = 0$ and different values of ν .

Lemma 3 helps us understand how the relative welfare advantage of revealing or not information on a recession depends on taxes, for given beliefs. Yet, in equilibrium, government's announcements also influence beliefs, since

posterior beliefs have to be derived from government's strategy via Bayes' rule along the equilibrium path of play. Recall that, when allowing for mixed strategies, we call $\rho = \Pr(m(-\vartheta) = H)$ and $\sigma = \Pr(m(\vartheta) = H)$.

Proposition 2 (Non babbling equilibria)

There are only two types of non babbling equilibria in pure strategies (pooling and separating) and one type in mixed strategies (semi-separating). In all cases, labor supply strategies are described by (1).

- *At a pooling equilibrium $m(\vartheta) = m(-\vartheta) = H$ and $\nu = p$. A pooling equilibrium exists if and only if $\mu < p$ and $t \geq t^*(\mu, p)$.*
- *At a separating equilibrium $m(-\vartheta) = L$, $m(\vartheta) = H$, $\mu = 0$ and $\nu = 1$. A separating equilibrium exists if and only if $t \leq t^*(0, 1)$.*
- *At a semi-separating equilibrium $\rho \in (0, 1)$, $\sigma = 1$, $\mu = 0$ and $\nu = \frac{p}{p+(1-p)\rho}$. A semi-separating equilibrium exists if and only if $t = t^*\left(0, \frac{p}{p+(1-p)\rho}\right)$.*

Proof Labour supply strategies follow from Lemma 1. Since the set of feasible messages comprises only two signals, there are only two types of pure strategy equilibria: either the government sends the same signal both in booms and in recessions, or it sends different signals. It is then without loss of generality to call H the message sent in booms.

Consider a candidate pooling equilibrium. The government sends the same message H both in booms and in recessions. Along the equilibrium path of play, i.e., upon receiving H , individuals do not learn anything and have to base decisions on their prior beliefs: Bayes' rule implies $\nu = p$. Then by Lemma 2, the government does not deviate in booms if and only if $\mu \leq p$. By Remark 2, $\mu \neq \nu$. So the only restriction on out of equilibrium beliefs is $\mu < p$. Given this, by Lemma 3, the government does not deviate in recessions if and only if $t \geq t^*(\mu, p)$.

Now consider a candidate separating equilibrium. The government announces H in booms and L in recessions. Bayes' rule then implies $\mu = 0$ and $\nu = 1$. Given this, by Lemma 2, the government does not deviate in booms. By Lemma 3, it does not deviate in recessions either if and only if $t \leq t^*(0, 1)$.

Now allow for mixed strategies. In booms the government is willing to mix if and only if $\mu = \nu$, which is excluded by Remark 2. So, as above without loss of generality, non babbling equilibria in mixed strategies imply $\mu < \nu$ and $\sigma = 1$, i.e., they may only be semi-separating. For $\rho \in \{0, 1\}$, we have the two pure strategy equilibria considered above. For $\rho \in (0, 1)$, Bayes' rule implies $\mu = 0$ and $\nu = \frac{p}{p+(1-p)\rho}$. Given this, by Lemma 2, the government does not deviate in booms. By Lemma 3, it does not deviate in recessions either if and only if $t = t^* \left(0, \frac{p}{p+(1-p)\rho}\right)$. ■

At a separating equilibrium the government sends different signals in different states of the world, so that workers can fully infer its private information. This implies that they respond to government's announcements by changing labor supply.

At a pooling equilibrium, the government sends the same signal in any state of the world, so that workers cannot infer any information from signals, and therefore supply the same amount of labor in any state of the world, irrespective of government's announcements. Observe that along the equilibrium path of play of a pooling equilibrium, workers exert as much work effort as in any babbling equilibrium, since in both cases they respond optimally to their prior beliefs. The only difference between pooling and babbling equilibria is in terms of out of equilibrium beliefs. At a pooling equilibrium, the government does not reveal information on a recession, precisely because its unsent signal L would receive a pessimistic interpretation ($\mu < \nu = p$), thus inducing a welfare decreasing reduction in labor supply. By contrast, in babbling equilibria the government is indifferent between the two signals, since they are disregarded ($\mu = \nu = p$). Indeed, in almost all such equilibria, there are no unsent signals, since the government sends any signal with a strictly positive probability, which is the same in booms and in recessions ($\rho = \sigma \in (0, 1)$).

At a semi-separating equilibrium, the government always announces H in booms, but it randomizes in recessions, sending the different signal L with probability $(1 - \rho)$ and the same signal H as in booms with probability $\rho \in (0, 1)$. Thus ρ may be interpreted as the degree of over-optimism by the government. The implication of over-optimism is that the government loses credibility, as compared with a separating equilibrium. Yet, since it sometimes sends a different signal in recessions from the signal it always sends in booms, its announcements retain a higher level of credibility, when compared

to the pooling equilibrium. As a consequence, labor supply responsiveness to government's announcements at a semi-separating equilibrium is at an intermediate level between the zero responsiveness of a pooling equilibrium and the full responsiveness of a separating equilibrium.

3.2 Efficiency and equilibrium selection

Let us now compare the different equilibria from an ex ante point of view, that is, when averages (or expected values) are based on the prior distribution of shocks. Consider first separating and pooling equilibria. For an individual with ability β , let $\bar{\ell}_\beta^S$, \bar{y}_β^S , \bar{u}_β^S , and $\bar{\ell}_\beta^P$, \bar{y}_β^P , \bar{u}_β^P , denote the ex ante expected levels of labor supply, production and indirect utility, at a separating and at a pooling equilibrium, respectively.

Proposition 3 (Ex ante Pareto dominance: pooling and separating)

For any parameter constellation, any ability distribution, and any level β of individual ability, the following holds: (i) $\bar{\ell}_\beta^S < \bar{\ell}_\beta^P \iff \delta > 2$; (ii) $\bar{y}_\beta^S > \bar{y}_\beta^P$; (iii) $\bar{u}_\beta^S > \bar{u}_\beta^P$.

Proof Let $\bar{\theta} = p\vartheta - (1-p)\vartheta$ be the expected value of θ according to prior beliefs. Labor supply by an individual with ability β , when the state of the world is θ , is $\ell_\beta^S(\theta) = (1-t)^{\frac{1}{\delta-1}}(\beta+\theta)^{\frac{1}{\delta-1}}$ at a separating equilibrium and $\ell_\beta^P(\theta) = \ell_\beta^P = (1-t)^{\frac{1}{\delta-1}}(\beta+\bar{\theta})^{\frac{1}{\delta-1}}$ at a pooling equilibrium. $y_\beta^S(\theta) = (\beta+\theta)\ell_\beta^S(\theta)$ and $y_\beta^P(\theta) = (\beta+\theta)\ell_\beta^P$ are the corresponding production levels; and $u_\beta^S(\theta) = (1-t)y_\beta^S(\theta) - \frac{[\ell_\beta^S(\theta)]^\delta}{\delta} + t \int_b^B y_\beta^S(\theta) dF(\beta)$ and $u_\beta^P(\theta) = (1-t)y_\beta^P(\theta) - \frac{(\ell_\beta^P)^\delta}{\delta} + t \int_b^B y_\beta^P(\theta) dF(\beta)$ are the corresponding levels of indirect utility. Ex ante expected levels of individual labor supply, individual production and individual indirect utility at the two equilibria are then, respectively, $\bar{\ell}_\beta^S = (1-t)^{\frac{1}{\delta-1}} \left[p(\beta+\vartheta)^{\frac{1}{\delta-1}} + (1-p)(\beta-\vartheta)^{\frac{1}{\delta-1}} \right]$ and $\bar{\ell}_\beta^P = \ell_\beta^P$; $\bar{y}_\beta^S = (1-t)^{\frac{1}{\delta-1}} \left[p(\beta+\vartheta)^{\frac{\delta}{\delta-1}} + (1-p)(\beta-\vartheta)^{\frac{\delta}{\delta-1}} \right]$ and $\bar{y}_\beta^P = (1-t)^{\frac{1}{\delta-1}} [\beta+\bar{\theta}]^{\frac{\delta}{\delta-1}}$; and $\bar{u}_\beta^S = \left(\frac{\delta-1}{\delta}\right) (1-t)\bar{y}_\beta^S + t \int_b^B \bar{y}_\beta^S dF(\beta)$ and $\bar{u}_\beta^P = \left(\frac{\delta-1}{\delta}\right) (1-t)\bar{y}_\beta^P + t \int_b^B \bar{y}_\beta^P dF(\beta)$. Points (i) and (ii) then immediately follow by convexity (or concavity), and point (iii) is a corollary of point (ii). ■

Notice that, for any parameter constellation and ability distribution, ex ante expected levels of individual labor supply, production and indirect util-

ity, whose relationships are identified in Proposition 3, are well defined, independently of whether a separating or a pooling equilibrium (or both) exist. Notice also that, along the equilibrium path of play, labor supply, and hence production and indirect utility, are the same at a pooling and at any babbling equilibrium. Therefore Proposition 3 establishes that, for any tax rate, transparent and credible revelation of information is ex ante Pareto superior to information hiding. Yet, as we already know from the previous analysis, high tax distortions may prevent the transparent outcome from materializing in equilibrium.

The intuition behind Propositions 3 is very simple. Transparency allows individuals to work more when they are more productive and less when they are less productive. This unequivocally raises the ex ante level of individual production, relative to no information disclosure. Although it also raises the ex ante level of individual disutility of labor (since workers dislike fluctuations in labor effort), this latter effect is always more than compensated by the higher expected level of individual consumption.¹⁹

If we now condition on equilibrium existence, and extend the analysis to any possible equilibrium, we have the following result.

Proposition 4 (Ex ante welfare dominance)

Whenever it exists, the separating equilibrium dominates any other equilibrium in terms of ex ante social welfare.

Proof When we compare the separating equilibrium with either a pooling or any babbling equilibrium, the result is a corollary of Proposition 3.²⁰ Now compare the separating with the semi-separating equilibrium.²¹ In recessions

¹⁹Transparency raises individual expected leisure time if the elasticity of labor supply is $\gamma < 1$ (i.e., for $\delta > 2$). In this case, labor supply is a concave function of expected wages. This implies that, relative to the case of no information, labor supply reductions in recessions are more pronounced than increases in booms. If the elasticity of labor supply is $\gamma > 1$ (i.e., for $\delta < 2$), by contrast, labor supply is a convex function of expected wages. In this case, transparency raises individual expected labor supply, relative to information hiding.

²⁰Observe that ex ante social welfare at the separating and at any pooling or babbling equilibrium can be written as $\bar{W}^S = \int_b^B \bar{u}_\beta^S dF(\beta) = \frac{\delta-1+t}{\delta} \int_b^B \bar{y}_\beta^S dF(\beta)$ and $\bar{W}^P = \int_b^B \bar{u}_\beta^P dF(\beta) = \frac{\delta-1+t}{\delta} \int_b^B \bar{y}_\beta^P dF(\beta)$, respectively.

²¹Recall that the separating equilibrium exists for $t \in (0, t^*(0, 1)]$; a pooling equilibrium exists if $\exists \mu : \mu < p$ and $t \geq t^*(\mu, p)$; a babbling equilibrium always exists; and a semi-separating equilibrium exists if $\exists \rho \in (0, 1) : t = t^* \left(0, \frac{p}{p+(1-p)\rho} \right)$. Existence of a

social welfare is the same in these two equilibria, since in the semi-separating the government is indifferent between signalling H and signalling L , but in this latter case labor supply and hence welfare are exactly the same as they are in recessions in the separating equilibrium (since in both cases $\mu = 0$).²² In booms, in turn, labor supply and welfare are higher in the separating than in the semi-separating equilibrium. ■

While it is analytically harder to prove ex ante Pareto dominance with respect to the semi-separating equilibrium, Proposition 4 adds to the previous results the higher ex ante efficiency, in terms of social welfare, of transparency even over partial disclosure. The intuition is the same as above.

Ex ante efficiency (or even Pareto dominance) thus clearly and univocally selects the separating equilibrium whenever it exists. Yet ex ante efficiency is not (always) a good selection criterion in the present context, because, whenever $t \in [t^*(0, p), t^*(0, 1)]$, government's preferences over equilibria are reversed in different states of the world: in booms the government would prefer to be in a separating equilibrium, in which it reveals its private information, thus boosting labor supply and welfare; in recessions it would prefer to be in any other equilibrium, in which information is not revealed, so that labor supply and welfare are higher than with perfect information.²³ It is therefore worthwhile to look at different equilibrium refinements.

For cheap talk games (Crawford and Sobel, 1982), standard refinements based on Kohlberg and Mertens (1986), which restrict off-the-equilibrium-path beliefs, have little power.²⁴ Other refinements, explicitly introduced to select equilibria in cheap talk games, are the No Incentive to Separate (NITS) criterion by Chen et al. (2008) and the Neologism-Proof (NP) equilibrium

semi-separating implies existence of a separating, which implies existence of a babbling equilibrium, whereas a pooling and the separating equilibria co-exist if $t^*(0, 1) \geq t \geq t^*(\mu, p)$.

²²When the government announces H in recession at a semi-separating equilibrium, its over-optimism induces a welfare loss from over-work (relative to the first best), which is exactly equal to the loss from under-work induced by full information revelation.

²³For the proof of this claim, see Remark 3 below. For the fact that $t^*(0, p) < t^*(0, 1)$, see Lemma 5 in Appendix B and its generalization in Appendix C.

²⁴This is true, for instance, for the Intuitive Criterion by Cho and Kreps (1987) and the Forward Induction Equilibrium by Cho (1987). To see this, notice that there always exist babbling equilibria, in which both signals are sent with strictly positive probability (and receive the same interpretation), so that all beliefs are formed along the equilibrium path of play.

by Farrell (1993).²⁵ The NITS criterion requires that the ‘lowest type’ of sender does at least as well in equilibrium as it would if it could fully reveal its type (and the receiver responded optimally). The idea is that, if this condition does not hold, then the ‘lowest type’ of sender would have an incentive to separate and would find a way to fully reveal its type, and since the receiver would understand such incentive, this revelation would be credible and would be used, thus breaking the equilibrium under consideration. In the present context, an equilibrium satisfies NITS if in recessions social welfare is (weakly) higher in equilibrium than it would be if workers were perfectly informed about the recession (and responded optimally).²⁶ The following remark shows that the NITS criterion, while ruling out some equilibria, is not very selective in our context.

Remark 3 (NITS)

The separating and semi-separating equilibria satisfy NITS.

Babbling and pooling equilibria satisfy NITS if and only if $t \geq t^(0, p)$.*

Proof Let $\theta = -\vartheta$. Social welfare under workers’ optimal response to perfect information is $W^S(-\vartheta) = \int_b^B \left\{ (\beta - \vartheta)\ell_\beta^S(-\vartheta) - \frac{[\ell_\beta^S(-\vartheta)]^\delta}{\delta} \right\} dF(\beta)$, where $\ell_\beta^S(-\vartheta) = (1 - t)^{\frac{1}{\delta-1}} (\beta - \vartheta)^{\frac{1}{\delta-1}}$. The separating equilibrium satisfies NITS, since workers, upon receiving message L , are indeed perfectly informed about the recession ($\mu = 0$) and respond optimally according to (1). Thus social welfare in recessions at the separating equilibrium is exactly $W^S(-\vartheta)$. At a semi-separating equilibrium, $\mu = 0$ and in recessions the government randomizes, implying that social welfare is $W^S(-\vartheta)$ as well. Thus, also the semi-separating equilibrium satisfies NITS. At any pooling or babbling equilibrium social welfare in recessions is $W^P(-\vartheta) = \int_b^B \left[(\beta - \vartheta)\ell_\beta^P - \frac{(\ell_\beta^P)^\delta}{\delta} \right] dF(\beta)$, where $\ell_\beta^P = (1 - t)^{\frac{1}{\delta-1}} (\beta + \bar{\theta})^{\frac{1}{\delta-1}}$ and $\bar{\theta} = p\vartheta - (1 - p)\vartheta$. Pooling and babbling equilibria satisfy NITS if and only if $W^P(-\vartheta) \geq W^S(-\vartheta)$. Using equations (2) and (3), we have that $W^P(-\vartheta) \geq W^S(-\vartheta) \iff [Z(t) \leq 0 \text{ for } \mu = 0 \text{ and } \nu = p] \iff t \geq t^*(0, p)$. ■

²⁵Both refinements are introduced for (two player) cheap talk games, with infinite type and message spaces. By contrast, our game features a continuum of workers and just two types and messages. None of these differences appears to matter for the following argument.

²⁶There is no ambiguity here about the fact that the ‘lowest type’ is a government in recession.

The intuition for the result on pooling and babbling equilibria is as follows. Social welfare in recessions is an inverted-U-shaped function of labor supply. For zero taxes, transparency allows to reach the first best, whereas hiding information implies overwork. As taxes increase, labor supply and welfare under transparency decrease, whereas overwork under information hiding decreases, thus raising the associated welfare. As long as $t < t^*(0, p)$, the welfare cost of under-work under transparency is lower than the welfare cost of over-work under information hiding, but as $t \geq t^*(0, p)$, the reverse is true. Unfortunately, NITS is only selective for very low tax rates. For instance, if $t \in [t^*(0, p), t^*(0, 1)]$, there exist separating, pooling, babbling and possibly also semi-separating equilibria, and all of them satisfy NITS.

Farrell (1993) proposes the stronger refinement of Neologism Proof (NP). An equilibrium is NP if there does not exist any self-signalling set. A self-signalling set is a (non empty) subset of ‘types’ (here, states of the world), which contains all and only those types who strictly gain, relative to their equilibrium outcome, by inducing the best response to the information that that they belong to that set. The idea is that, if such a set existed, this would destroy an equilibrium, since a neologism claiming “My type belongs to this set”, if interpreted literally, would be used by all the types in the set, who are the only ones who strictly gain by inducing a best response to the neologism’s literal meaning; this use, in turn, would justify the literal interpretation; but the credible use of the neologism would indeed destroy the considered equilibrium.

Remark 4 (Neologism Proof)

The separating equilibrium is NP whenever it exists.

Babbling and pooling equilibria are NP if and only if both $t \geq t^(0, p)$ and $t > t^*(p, 1)$.*

Semi-separating equilibria are NP if and only if $t > t^(0, 1)$.*

Proof For each equilibrium, we need to check that there does not exist any self-signalling set. In our model, a self-signalling set is a (non empty) set $G \subseteq \{-\vartheta, \vartheta\}$ such that $G = \{\theta : W(\ell^*(G)|\theta) > W^*(\theta)\}$, where $W(\ell^*(G)|\theta)$ denotes social welfare when the state of the world is θ and workers best respond to the information that $\theta \in G$, whereas $W^*(\theta)$ is social welfare when the type is θ in the considered equilibrium. We denote equilibrium social welfare when the type is θ , $W^*(\theta)$, by $W^S(\theta)$, $W^P(\theta)$ and $W^{SS}(\theta)$ at a separating, pooling, and semi-separating equilibrium, respectively.

For the separating equilibrium, $G = \{\vartheta\}$ and $G = \{-\vartheta\}$ are trivially not self-signalling, since $W(\ell^*(\{\theta\})|\theta) = W^S(\theta)$, for $\theta = -\vartheta, \vartheta$. $G = \{-\vartheta, \vartheta\}$ is also not self-signalling, because $\vartheta \notin G$, since $W(\ell^*(\{-\vartheta, \vartheta\})|\vartheta) = W^P(\vartheta)$, and we know that $W^S(\vartheta) > W^P(\vartheta)$, contradicting the definition of a self-signalling set.

For babbling and pooling equilibria, $G = \{-\vartheta, \vartheta\}$ is trivially not self-signalling, since $W(\ell^*(\{-\vartheta, \vartheta\})|\theta) = W^P(\theta)$, for $\theta = -\vartheta, \vartheta$. In turn, $G = \{\vartheta\}$ is self-signalling if and only if $t \leq t^*(p, 1)$; and $G = \{-\vartheta\}$ is self-signalling if and only if $t < t^*(0, p)$. To see this, consider first $G = \{\vartheta\}$. We have $\vartheta \in G$ since $W^S(\vartheta) > W^P(\vartheta)$; and we have $-\vartheta \notin G \iff W^P(-\vartheta) \geq W(\ell^*(\{\vartheta\})|-\vartheta)$, which, using (2) and (3), is equivalent to $Z(t) \geq 0$ for $\mu = p$ and $\nu = 1$, which holds if and only if $t \leq t^*(p, 1)$. Now consider $G = \{-\vartheta\}$. We have $\vartheta \notin G$ since $W^P(\vartheta) > W(\ell^*(\{-\vartheta\})|\vartheta)$; and we have $-\vartheta \in G \iff W^S(-\vartheta) > W^P(-\vartheta) \iff Z(t) > 0$ for $\mu = 0$ and $\nu = p$, which holds if and only if $t < t^*(0, p)$.

For semi-separating equilibria recall that $W^{SS}(-\vartheta) = W^S(-\vartheta)$. $G = \{\vartheta\}$ is self-signalling if and only if $t \leq t^*(0, 1)$, because $\vartheta \in G$ since $W^S(\vartheta) > W^{SS}(\vartheta)$; and we have $-\vartheta \notin G \iff W^S(-\vartheta) \geq W(\ell^*(\{\vartheta\})|-\vartheta) \iff Z(t) \geq 0$ for $\mu = 0$ and $\nu = 1$, which holds if and only if $t \leq t^*(0, 1)$. In turn, $G = \{-\vartheta\}$ is not self-signalling, because $-\vartheta \notin G$ since $W^{SS}(-\vartheta) = W^S(-\vartheta)$. $G = \{-\vartheta, \vartheta\}$ is also not self-signalling, because $\vartheta \notin G$, since $W^{SS}(\vartheta) > W^P(\vartheta)$. ■

As already mentioned, from Lemma 5 in Appendix B, whose scope is extended in Appendix C, we know that, for a great variety of parameter constellations and distributional assumptions, it holds that $t^*(\mu, \nu)$ is strictly increasing in its arguments (in the range of μ and ν such that $0 \leq \mu < \nu \leq 1$). This monotonicity property implies that semi-separating equilibria are never NP, since they do not exist for $t > t^*(0, 1)$. Moreover, since $t^*(p, 1) > t^*(0, 1) > t^*(0, p)$, it also implies that pooling equilibria are NP if and only if $t > t^*(p, 1)$, that is, only when the separating equilibrium does not exist.²⁷ This proves the following remark.

²⁷For $t \in (t^*(0, 1), t^*(p, 1)]$, there doesn't exist any NP equilibrium. The fact that an NP equilibrium may fail to exist often raises the concern that it is too strong a refinement. Yet we find it convincing that, whenever existing, the separating equilibrium always satisfies even this strong refinement, and that, as stated in Remark 5, under mild conditions the NP criterion univocally selects the separating equilibrium whenever existing.

Remark 5 (Unique selection of separating whenever existing)

If $t^(\mu, \nu)$ is strictly increasing in its arguments, then whenever the separating equilibrium exists, i.e. for $t \leq t^*(0, 1)$, it is the only NP equilibrium.*

The intuition for the fact that the separating equilibrium is NP is that, for low tax distortions, in any state of the world the government prefers to have workers perfectly informed about it than fooled and fully convinced of the opposite, and in booms it prefers transparency to hiding information, so that indeed no self-signalling set exists. The intuition for uniqueness is that any other equilibrium, which is not fully transparent, is not NP for low tax rates, because in that case social welfare in booms would be strictly higher than in equilibrium if the government could find a credible neologism that fully reveals the boom, and in turn this neologism would be credible because, in recessions, the government would not use it, since cheating workers, if believed, would induce overwork and reduce social welfare below its equilibrium level.

Summing up, for $t \leq t^*(0, 1)$, the separating equilibrium appears the most natural prediction of the game. Besides its efficiency properties (stated in Propositions 3 and 4), Remarks 3 and 4 show that, whenever it exists, it satisfies both NITS and NP, and Remark 5 shows that, under a mild monotonicity condition that holds for many parameter constellations and distributional assumptions, the separating equilibrium, whenever existing, is the only NP equilibrium.

3.3 Transparency, shocks and inequality

In light of the above discussion, for the remainder of the paper we assume that the economy coordinates on the separating equilibrium whenever it exists. Such assumption leads to the following remark.

Remark 6 (Equilibrium transparency for low tax distortions)

Equilibrium government information is transparent whenever $t \leq t^(0, 1)$.*

The main comparative statics exercise then amounts to investigate how the relevant threshold for existence of a separating equilibrium, $t^*(0, 1)$, moves in response to parameter or distributional changes. We refer to the tax rate interval $[0, t^*(0, 1)]$ as to the support of transparency, and say that pa-

parameter or distributional changes favor (reduce) transparency if they increase (decrease) $t^*(0, 1)$.²⁸

Proposition 5 (Effects of shock magnitude)

For any parameter constellation and distributional assumption, an increase in shock magnitude, ϑ , favors transparency.

Proof Given posterior beliefs $\mu = 0$ and $\nu = 1$, and exploiting the fact that $(\beta - \vartheta) = (\beta + \vartheta - 2\vartheta)$, from equation (2) we can derive $\frac{\partial Z(t)}{\partial \vartheta} = \frac{\delta-1+t}{\delta-1} \int_b^B \left[(\beta + \vartheta)^{\frac{1}{\delta-1}} - (\beta - \vartheta)^{\frac{1}{\delta-1}} \right] dF(\beta) + \frac{2\vartheta}{\delta-1} \int_b^B (\beta + \vartheta)^{\frac{2-\delta}{\delta-1}} dF(\beta) > 0$. ■

In light of Remark 6, Proposition 5 tells us that, to have transparency in equilibrium, what matters is that tax distortions are small *relative* to the importance of aggregate shocks. This is due to the fact that credible and benevolent governments face a trade-off in recessions: they can hide private information on negative aggregate shocks to stimulate the economy and compensate for suboptimal labor supply due to taxes, but if they do so, they impose an information distortion. When taxes are low relative to the importance of aggregate shocks, the costs of overwork caused by cheating in recessions exceed the costs of under-supply of labor due to taxes, and the government reveals its private information. When taxes are high relative to the importance of aggregate shocks, the reverse is true. An increase in shock magnitude raises the distortion caused by information hiding in recessions, relative to the tax distortion suffered under transparency. It thus favors transparency.

Notice that while shock magnitude is important, concerning shock frequency we have the following remark.

Remark 7 (Effects of shock frequency)

For any parameter constellation and distributional assumption, the frequency of booms and recessions is irrelevant for transparency.

Proof Just observe that $t^*(0, 1)$ is determined by the welfare comparison between announcing L and H , conditional upon being in recession. ■

²⁸Recall from equations (2) and (3) that $t^*(0, 1)$ is obtained by equating to zero $Z(t)$ for posterior beliefs $\mu = 0$ and $\nu = 1$. Recall as well that the first term of $Z(t)$ reflects the overall leisure utility gain caused by announcing L , relative to H , in recessions; the second term reflects the corresponding overall consumption utility loss.

It is interesting to observe that this implies no discontinuity of equilibrium informational policy as fluctuations vanish. In particular, suppose $t > t^*(0, 1)$, so the government is non informative in equilibrium. As p approaches 1, the economy is almost always in booms, the government always announces H and the corresponding posterior belief $\nu = p$ also converges to 1, so essentially we have truth-telling. The non informative equilibrium converges to the informative one, since posterior beliefs are based on the prior distribution of aggregate shocks, which becomes degenerate. Similarly, as p approaches 0, the economy is almost always in recession, the government always announces H , but now the corresponding posterior belief $\nu = p$ converges to 0, so essentially the equilibrium meaning of H , as interpreted by the agents, is “We are in recession”, and again we have truth-telling, so no discontinuity. The only difference is that, if H has a natural meaning “We are in boom”, in this case its equilibrium meaning does not coincide with its natural meaning. Indeed, the government keeps saying “We are in boom”, but since rational individuals know the prior distribution of aggregate shocks, they do not believe such announcement and rather interpret it according to their prior knowledge. But since the government knows this, it lies knowing that it will not be believed and that individuals are essentially perfectly informed anyway, which is what the government cares about.

Let us now consider the effects of inequality on transparency. In the next proposition, we use Lorenz dominance (second order stochastic dominance) as a criterion to establish whether a distribution has more inequality than another one.

Proposition 6 (Effects of inequality)

For any parameter constellation and distributional assumption, the effects of skill inequality on transparency depend on labor supply elasticity. In particular, consider a shift from skill distribution F to a more unequal distribution G , dominated by F with respect to second order stochastic dominance.

- *If $\gamma = 1$, such increase in inequality has no effects on transparency.*
- *If $\gamma < 1$, it favors transparency.*
- *If $\gamma > 1$, letting $\hat{\gamma} = \frac{2}{1-t^*(0,1)} > 2$, we have that $\gamma \in (1, \hat{\gamma}]$ is a sufficient condition for it to reduce transparency.*

Proof Given posterior beliefs $\mu = 0$ and $\nu = 1$, from equation (2), we can write

$$Z(t) = \int_b^B z(\beta) dF(\beta),$$

where

$$z(\beta) = \frac{1-t}{\delta} \left[(\beta + \vartheta)^{\frac{\delta}{\delta-1}} - (\beta - \vartheta)^{\frac{\delta}{\delta-1}} \right] - (\beta - \vartheta) \left[(\beta + \vartheta)^{\frac{1}{\delta-1}} - (\beta - \vartheta)^{\frac{1}{\delta-1}} \right].$$

By Jensen's inequality, if $z(\beta)$ is a convex function of β at $t = t^*(0, 1)$, then an increase in inequality (in the distribution of productivity) will determine a rise in $Z(t)$ and consequently a rise in $t^*(0, 1)$. By contrast, if $z(\beta)$ is concave at $t = t^*(0, 1)$, then inequality will reduce $t^*(0, 1)$. The proposition is then a corollary of Lemma 4 in Appendix, which investigates how the convexity or concavity of $z(\beta)$ depends on δ . To see this, just recall that $\gamma = \frac{1}{\delta-1}$, so that $\gamma \leq 1 \iff \delta \geq 2$. Moreover, $t^*(0, 1) \in (0, 1)$ and, for any $t \in (0, 1)$, $\delta \geq \frac{3-t}{2} \iff \gamma \leq \frac{2}{1-t}$. ■

First notice that most of the literature on information transparency assumes $\gamma = 1$ (which means linear labor supply) and thus assumes away the effects of inequality. We elaborate below on the special case of linear labor supply. Yet the general picture is that inequality matters for government transparency, and the way it does so depends on the shape of the labor supply curve. In particular, for plausible values of labor supply elasticity (i.e., for $\gamma < 1$), inequality favors transparency.

To grasp the intuition for this result, notice that $t^*(0, 1)$ depends on the welfare comparison between (credibly) revealing and not revealing information about a recession. Given welfare convexity, inequality raises welfare under both communication regimes, so the comparison depends on whether inequality raises welfare *faster* under transparency than under information hiding. Given our preferences, while production is always convex in ability, labor supply is concave whenever it is rigid ($\gamma < 1$). In this case, in recessions an increase in inequality lowers aggregate (or, which is the same, average, across the population) labor supply and raises aggregate (or average) production and welfare. Transparency in recessions raises leisure and reduces consumption, relative to information hiding, for each individual. Both the individual utility gain from transparency due to higher leisure and that from information hiding due to higher consumption, relative to the other communication regime, are convex in ability. In Proposition 6 we prove that, for

$\gamma < 1$ (and for any tax rate), also their difference, i.e., the overall individual utility gain from transparency, relative to information hiding, is convex in ability. In other words, with rigid labor supply, the leisure component prevails on the consumption component in determining (for any tax rate) the convexity of the relative utility gain to transparency. Thus an increase in inequality indeed raises welfare in recessions *faster* under transparency than under information hiding, and so it expands the support for transparency. By contrast, for elastic labor supply, the consumption component prevails over the leisure component in determining the concavity of the relative utility gain to transparency, thus the result is reversed.²⁹

Last, an analytical characterization of the direct effects of labor supply elasticity on $t^*(0, 1)$, for any possible constellation of other parameters and for any ability distribution, is hard to obtain. Numerical investigation under the assumption of a Pareto distribution of β yields the following remark.

Remark 8 (Effects of labor supply elasticity)

Whether labor supply elasticity favors or not transparency cannot be established in general terms. For high but plausible values of inequality (Gini index above 1/3), it tends to harm transparency. For lower values of inequality, in turn, it tends to have a non linear effect, initially favoring and then harming transparency. In this case, the quantitative effect appears to be small.

4 The Politico-Economic Equilibrium

We have considered so far the informational policy of the government for a given tax rate. We have obtained that whether or not the government is transparent critically depends on the existing tax rate being above or below of a threshold level. The value of this threshold turns out to depend on the level of inequality. But, the ruling tax rate will plausibly also depend on the degree of inequality. This is certainly the case when the tax rate is chosen by majority voting. Therefore, in order to complete the model we need to examine the politico-economic equilibrium of the economy, in which the outcome of majority voting is consistent with the conditions for the existence of a given informational policy.

²⁹In detail, we show that this is true for any tax rate when $\gamma \in (1, 2]$, and that it continues to hold at $t = t^*(0, 1)$ at least for an interval of $\gamma > 2$. While we cannot offer a proof of the result for any possible higher value of labor supply elasticity, such values are indeed contrary to any empirically plausible estimate of γ .

We now proceed to the analysis of the choice of tax rates under majority voting, focusing on pure strategy equilibria of the announcements game and assuming skewed skill distributions with the median below the mean. Denoting by β_m the median skill, i.e., $F(\beta_m) = \frac{1}{2}$, we assume $\beta_m \leq E(\beta)$. We follow the standard analysis by Meltzer and Richard (1981). As we have already mentioned, the alternative informational policies generate distinct regimes. Under truthful information individuals choose labor supply in a regime of income fluctuations with perfect certainty about the state of the world. In the other regime the government's announcements are not informative and individuals are uncertain about the true state of the world when they make labor supply choices. We first solve for the majoritarian tax under each informational policy and then examine the existence and properties of the politico-economic equilibrium.

4.1 Voting over taxes

In a model which is essentially identical to ours, fluctuations and our assumption of separable preferences, Meltzer and Richard (1981) prove that, if consumption and leisure are normal goods, then preferences over taxes are monotonically decreasing in individual income, so that the decisive voter will be the voter with median income. In particular, they show that the tax rate chosen by the median voter equalizes the elasticity of mean income to the tax rate (in absolute value) and the complement to one of the ratio of median to mean income.

We differ from their model in that we introduce fluctuations due to aggregate productivity shocks and, if the government is non informative, uncertainty about individual productivity. Neither of these differences modifies their result, once we reformulate it in terms of expected income. In our model, as in theirs, consumption is a normal good. By contrast, our assumptions on preferences eliminate any income effect on labor supply, so that leisure is neither normal nor inferior. Yet notice that the only role of the assumption that leisure is a normal good is to assure that, for any tax rate, there is a unique level of transfers that balances the government budget. If leisure is a normal good, this holds because transfers reduce labor supply and hence mean income (see Meltzer and Richard, 1981, pp. 919-920). In our model, mean income is independent of transfers, so this result holds as well.

We can therefore apply the standard analysis of Meltzer and Richard (1981) and obtain the tax rate selected by the decisive voter under the two

information regimes. Let superscripts S and P denote a fully informative and a non informative regime, respectively. Since income is monotonic in individual skills, the median income is the income of an individual with median skill, β_m , and this is indeed the decisive voter. In regime $i = S, P$, the ex ante expected median income is $\bar{y}_{\beta_m}^i$ and the per capita expected income is $E(\bar{y}_\beta^i) = \int_b^B \bar{y}_\beta^i dF(\beta)$. Denoting $K(x) \equiv \int_b^B (\beta + x)^{\frac{\delta}{\delta-1}} dF(\beta)$, for $x = \vartheta, -\vartheta, \bar{\theta}$, we can state the following proposition.

Proposition 7 (Majoritarian tax rate)

Given the government's information policy, the median voter selects a tax rate $t^i \in (0, 1)$ such that

$$-\frac{t^i}{E(\bar{y}_\beta^i)} \frac{dE(\bar{y}_\beta^i)}{dt} = 1 - \frac{\bar{y}_{\beta_m}^i}{E(\bar{y}_\beta^i)},$$

where $i = S$ if the government is informative and $i = P$ if it is non informative. Explicit calculation yields

$$t^S = 1 - \frac{1}{\delta - (\delta - 1) \frac{p(\beta_m + \vartheta)^{\frac{\delta}{\delta-1}} + (1-p)(\beta_m - \vartheta)^{\frac{\delta}{\delta-1}}}{pK(\vartheta) + (1-p)K(-\vartheta)}},$$

$$t^P = 1 - \frac{1}{\delta - (\delta - 1) \frac{(\beta_m + \bar{\theta})^{\frac{\delta}{\delta-1}}}{K(\bar{\theta})}}.$$

Proof Although the characterization in terms of median and mean income immediately follows from Meltzer and Richard (1981), we provide an explicit derivation. Recall from the proof of Proposition 3 that, for $i = S, P$ and for any β and t , the ex ante expected level of individual indirect utility in information regime i is $\bar{u}_\beta^i = \left(\frac{\delta-1}{\delta}\right) (1-t)\bar{y}_\beta^i + tE(\bar{y}_\beta^i)$. Taking the first derivative with respect to t , and observing that $(1-t)\frac{d\bar{y}_\beta^i}{dt} = -\left(\frac{1}{\delta-1}\right)\bar{y}_\beta^i$, we have the first order condition $\frac{d\bar{u}_\beta^i}{dt} = E(\bar{y}_\beta^i) - \bar{y}_\beta^i + t^i \frac{dE(\bar{y}_\beta^i)}{dt} = 0$. This characterizes the most preferred tax rate (for β) whenever labor supply is strictly positive (which holds for every β in our model) and whenever a solution exists in the range $t \in (0, 1)$. Observe that $\frac{d\bar{u}_\beta^i}{dt} < 0$ as t is sufficiently close to 1, since labor supply and income become close to 0. So we necessarily have $t^i < 1$. Moreover, since $\frac{d\bar{u}_\beta^i}{dt}$ can be written as the product of $(1-t)^{\frac{1}{\delta-1}}$ and a term Q_β^i that is strictly decreasing in t , it follows that, if an interior solution exists,

it is unique and it defines a maximum; otherwise, the most preferred tax is zero. Specifically, for $i = S, P$, we can write $\frac{d\bar{u}_\beta^i}{dt} = (1-t)^{\frac{1}{\delta-1}} Q_\beta^i$, where $Q_\beta^S = \left[1 - \frac{t}{(\delta-1)(1-t)}\right] [pK(\vartheta) + (1-p)K(-\vartheta)] - \left[p(\beta + \vartheta)^{\frac{\delta}{\delta-1}} + (1-p)(\beta - \vartheta)^{\frac{\delta}{\delta-1}}\right]$ and $Q_\beta^P = K(\bar{\theta}) - (\beta + \bar{\theta})^{\frac{\delta}{\delta-1}} - \frac{t}{(\delta-1)(1-t)} K(\bar{\theta})$. Let $t^i(\beta)$ be the solution by t of $Q_\beta^i = 0$. For the median voter such values are $t^i = t^i(\beta_m)$, as expressed in the proposition. To see that $t^i > 0$, notice that $t^i(\beta)$ is strictly decreasing in β . Moreover, using standard properties of convex functions, we know that $pK(\vartheta) + (1-p)K(-\vartheta) > p(E(\beta) + \vartheta)^{\frac{\delta}{\delta-1}} + (1-p)(E(\beta) - \vartheta)^{\frac{\delta}{\delta-1}}$ and $[E(\beta) + \bar{\theta}]^{\frac{\delta}{\delta-1}} < \int_b^B (\beta + \bar{\theta})^{\frac{\delta}{\delta-1}} dF(\beta)$. So $t^i(E(\beta)) > 0$. Hence, $\beta_m \leq E(\beta)$ implies that $t^i = t^i(\beta_m) \geq t^i(E(\beta)) > 0$, for $i = S, P$. ■

4.2 Politico-Economic Equilibrium

We have just determined the tax rate selected by the median voter for each given government information regime. In the previous sections we established that, given the tax rate, the equilibrium of the announcement game is informative if $t \leq t^*(0, 1)$, and non informative otherwise. We now verify whether the tax rate selected by the median voter under each possible information regime is indeed consistent with that regime. The tax rate t^S and an informative policy by the government constitute a politico-economic equilibrium if and only if $t^S \leq t^*(0, 1)$. In turn, t^P and a non-informative policy constitute a politico-economic equilibrium if and only if $t^P > t^*(0, 1)$.

The conditions for these inequalities to hold are hard to express for a general value of δ . Both the threshold $t^*(0, 1)$ and the majoritarian tax rate depend on the degree of inequality. The wider the gap between median and mean income, the higher the tax rate preferred by the median voter. However, as we have seen in the previous Section, the effect of higher inequality on the threshold tax level depends on δ . When $\delta > 2$ inequality raises the threshold level and when $\delta < 2$ inequality lowers this threshold level.

For the remainder of this Section we restrict to the case of $\delta = 2$, which corresponds to linear labor supply. Moreover, for clarity of exposition, we focus on the standard case of white noise shocks, that is, with $\bar{\theta} = 0$. The extension to the case of $\bar{\theta} \neq 0$ is straightforward and is discussed below, together with the implications for the case of $\delta \neq 2$. Denote by $\epsilon \equiv \frac{\vartheta}{E(\beta)}$ the relative size of the shock; by $v \equiv \frac{V(\beta)}{E(\beta)^2}$ the normalized skill variance, where

$V(\beta) = \int_b^B [\beta - E(\beta)]^2 dF(\beta)$; and by $\psi \equiv \left[\frac{\beta_m}{E(\beta)} \right]^2$ the square of the median to mean ratio. Using subscript L for the case of linear labor supply, we then have $t^*(0, 1) = t_L^*(0, 1)$ and $t^i = t_L^i$ for $i = S, P$, where

$$\begin{aligned} t_L^*(0, 1) &= \epsilon, \\ t_L^S &= \frac{1 - \psi + v}{2 - \psi + 2v + \epsilon^2}, \\ t_L^P &= \frac{1 - \psi + v}{2 - \psi + 2v}. \end{aligned}$$

The case of $\delta = 2$ is a useful benchmark because the threshold tax is independent of inequality and hence we just need to examine the conditions under which the chosen tax will be larger or smaller than the fix value ϵ .³⁰ So the larger the relative shock magnitude, the wider the range of taxes that induce an informative policy by the government. Concerning t_L^S and t_L^P , it is immediate to derive the following remarks, which also hold for $\bar{\theta} \neq 0$.

Remark 9 (Effects of shocks and inequality on taxes)

Both t_L^S and t_L^P are increasing in the normalized skill variance v and decreasing in the (squared) median to mean ratio ψ . Moreover, t_L^S is decreasing in the normalized shock magnitude ϵ , whereas t_L^P is independent of ϵ .

Remark 10 (Comparison between t_L^S and t_L^P)

$t_L^S \leq t_L^P$, with equality if and only if $v = \infty$. The distance between t_L^P and t_L^S increases in ϵ .

In words, inequality raises the tax rate selected by the median voter under each information regime. The median voter chooses lower taxes in the informative than in the non-informative regime. The difference in majoritarian tax rates between these two cases is increasing in the importance of information (or, which is the same, of aggregate shocks).

Observe that, for any distribution, any value of $\psi \in (0, 1)$ imposes a lower bound $(\sqrt{\psi} - 1)^2$ to the values of v compatible with it.³¹ So any

³⁰See Remark 11 in Appendix B. Notice that $t_L^*(0, 1) = \epsilon$ also holds for $\bar{\theta} \neq 0$.

³¹For any $F(\beta)$, given the squared median to mean ratio ψ , since the normalized variance v is a convex function of β , it is minimized by concentrating $\frac{1}{2}$ of the normalized distribution on $\sqrt{\psi}$ and $\frac{1}{2}$ on $(2 - \sqrt{\psi})$. Hence, $v \geq (\sqrt{\psi} - 1)^2$.

feasible combination of v and ψ has to satisfy the restriction $v \geq (\sqrt{\psi} - 1)^2$. We are now ready to state existence and characterize the politico-economic equilibrium.

Proposition 8 (Politico-economic equilibrium)

Assume $\delta = 2$, $\bar{\theta} = 0$, and $\psi \leq 1$. Let $g(\psi, \epsilon) \equiv \frac{1-\epsilon}{1-2\epsilon}\psi - 1$. For any ability distribution and any feasible combination of ϵ , v and ψ , a politico-economic equilibrium exists.

- If $\epsilon \geq \frac{1}{2}$, then the equilibrium is informative, with tax rate t_L^S .
- If $\epsilon < \frac{1}{2}$, then the following holds.
 - for $v \leq g(\psi, \epsilon)$, the equilibrium is informative, with tax rate t_L^S ;
 - for $v > g(\psi, \epsilon) + \frac{\epsilon^3}{1-2\epsilon}$, the equilibrium is non informative, with tax rate t_L^P ;
 - for $v \in \left(g(\psi, \epsilon), g(\psi, \epsilon) + \frac{\epsilon^3}{1-2\epsilon}\right]$, then both an informative and a non informative equilibrium exist, with respective tax rate t_L^S and t_L^P .

Proof For $\epsilon \geq \frac{1}{2}$, we have $t_L^S \leq t_L^P \leq t_L^*(0, 1)$. Now consider $\epsilon < \frac{1}{2}$. In this case, $t_L^S \leq t_L^*(0, 1) \iff v \leq g(\psi, \epsilon) + \frac{\epsilon^3}{1-2\epsilon}$ and $t_L^P > t_L^*(0, 1) \iff v > g(\psi, \epsilon)$. ■

Proposition 8 conveys the following message. Because the median voter is never going to select a tax rate on the decreasing side of the Laffer curve, the majoritarian tax rate is at most $\frac{1}{2}$. If $t_L^*(0, 1) \geq \frac{1}{2}$, the majoritarian tax is necessarily below it and the unique equilibrium is informative, with tax rate t_L^S . In turn, if $t_L^*(0, 1) < \frac{1}{2}$, then at low levels of inequality the majoritarian tax rate is below $t_L^*(0, 1)$, independently of government information policy, so the unique equilibrium is again informative, with tax rate t_L^S ; at high levels of inequality the majoritarian tax rate is instead above $t_L^*(0, 1)$, again independently of government information policy, so the unique equilibrium is non informative, with tax rate t_L^P ; at intermediate levels of inequality, in turn, we have that $t_L^S \leq t_L^*(0, 1) < t_L^P$, so that there are two equilibria: one in which the government is informative and the majoritarian tax rate is t_L^S ,

and one in which the government is non informative and the majoritarian tax rate is t_L^P .

Given the relative importance of aggregate shocks ϵ (and therefore given $t_L^*(0, 1)$), the measure on inequality that determines what kind of equilibrium exists depends on two features of the skill distribution: its normalized variance v and the (squared) median to mean ratio ψ . Increasing (in a feasible way) either the variance or the distance between the median and the mean (or both) moves towards higher taxes and non informative equilibria.

Figure 2 gives a qualitative representation of these results, given $\epsilon < \frac{1}{2}$. The feasible combinations of v and ψ satisfy $v \geq (\sqrt{\psi} - 1)^2$; among those, the informative equilibrium exists in the area below the upper solid line, whereas the non informative equilibrium exists in the area above the lower solid line; between the two solid lines, they both exist.

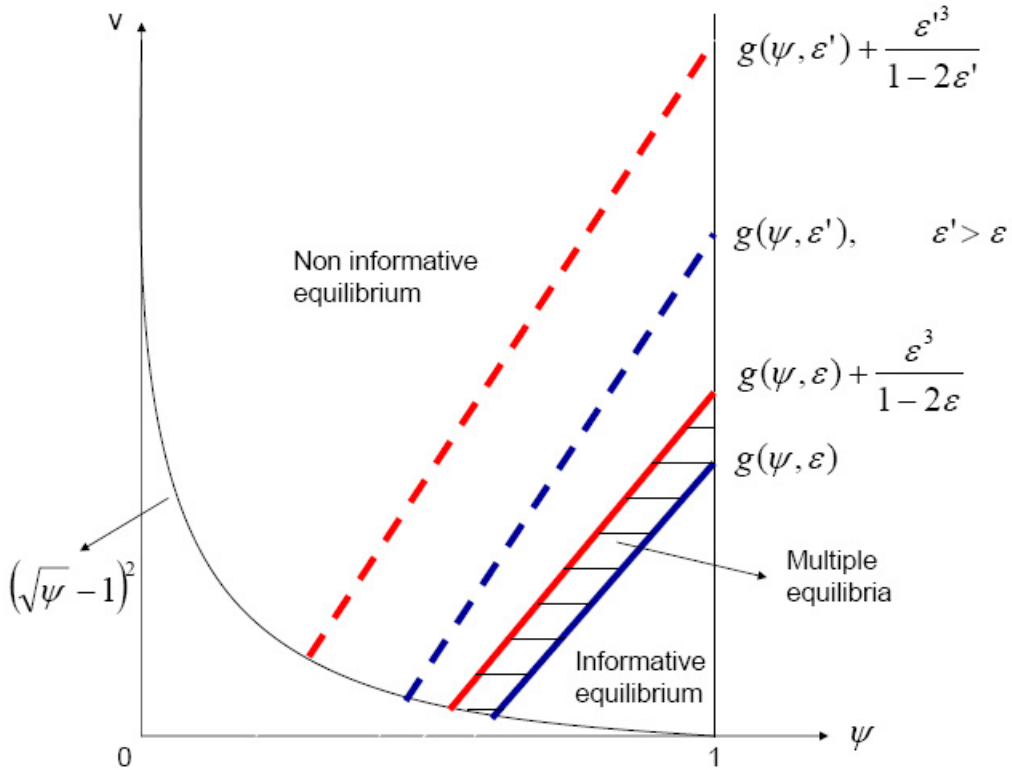


Figure 2: The politico-economic equilibrium under the assumptions of Proposition 8, with $\epsilon < \frac{1}{2}$.

Comparative statics on shock magnitude and inequality is then straight-

forward. Since we already discussed how majoritarian taxes depend on ϵ , v and ψ , and since for $\epsilon \geq \frac{1}{2}$ there is (always) a unique equilibrium (which is informative), we limit our discussion to the case of $\epsilon < \frac{1}{2}$ and to the effects of parameter and distributional changes on the existence range of informative and non informative politico-economic equilibria.

Proposition 9 (Effects of shock magnitude)

Let $\epsilon < \frac{1}{2}$. Under the assumptions of Proposition 8, an increase in shock magnitude ϵ

- expands the existence range of informative equilibria;
- reduces the existence range of non informative equilibria.

Proof Given $\epsilon < \frac{1}{2}$, consider first $g(\psi, \epsilon) + \frac{\epsilon^3}{1-2\epsilon}$ as a function of ψ . A rise in ϵ raises its vertical intercept and makes it steeper, thus expanding the set of feasible pairs (ψ, v) such that $t_L^S \leq t_L^*(0, 1)$. Now consider $g(\psi, \epsilon)$ as a function of ψ . A rise in ϵ makes it steeper, although its vertical intercept is always $g(0, \epsilon) = -1$, for any $\epsilon \in (0, 1)$. Thus a rise in ϵ reduces the set of feasible pairs (ψ, v) such that $t_L^P > t_L^*(0, 1)$. ■

The effects of a rise in ϵ are represented in Figure 2 by a shift from the solid to the dashed lines.³² In turn, the effects of a rise in inequality, as measured by the (normalized) variance or by the (squared) median to mean ratio, are described in the following proposition.³³

Proposition 10 (Effects of inequality)

Under the assumptions of Proposition 8, the following holds.

- For any $\epsilon < \frac{1}{2}$, if inequality is sufficiently low, the informative equilibrium exists. To be precise, there is a positive measure set of feasible pairs (ψ, v) , sufficiently close to $(1, 0)$, where it exists.

³²Notice that, while Figure 2 is accurate in the qualitative features, quantitatively it over-expands the range of multiple equilibria and overlooks the convergence of the lower solid and dashed lines at $\psi = 0$. This is done to make it easier to read.

³³Since for normalized distributions a shift to a dominated distribution with respect to second order stochastic dominance implies an increase in (normalized) variance, we could easily rephrase Proposition 10 in terms of such increases in inequality, as we did in Proposition 6. The variance formulation is just more straightforward for the case of linear labor supply.

- *Starting from one such pair, there exists a sufficient increase in v , such that only the non-informative politico-economic equilibrium exists.*

Proof Let $\epsilon < \frac{1}{2}$. Both the slope and the vertical intercept of $g(\psi, \epsilon) + \frac{\epsilon^3}{1-2\epsilon}$, considered as a function of ψ , tend to infinity as $\epsilon \rightarrow \frac{1}{2}$. In turn, $g(1, \epsilon) + \frac{\epsilon^3}{1-2\epsilon} = \frac{\epsilon^2+1}{1-2\epsilon}\epsilon \rightarrow 0$ as $\epsilon \rightarrow 0$. Then both results are a direct corollary of Proposition 8 and the following discussion. ■

Given $\delta = 2$ and $\bar{\theta} = 0$, the above analysis yields two results. First, inequality does not affect transparency when aggregate shocks are very important. This is due to the fact that majoritarian taxes cannot be too high, because of the inverted-U shape of the Laffer curve. Second, inequality clearly reduces transparency at lower levels of shock magnitude, because it raises majoritarian tax rates, eventually driving them outside the range, for which transparency is an equilibrium.³⁴

Let us now consider the generalizability of the results obtained in this section. In the case of $\bar{\theta} \neq 0$, the only difference would be that the majoritarian tax rate in each information regime would be decreasing in the frequency of booms p , so that, given $\delta = 2$, a rise in p expands the support for transparent equilibria and shrinks the support for non-informative equilibria. While this would change the precise formulation of the thresholds in Proposition 8, it would not modify any other qualitative result.

If $\delta < 2$, inequality raises majoritarian taxes and reduces the threshold $t^*(0, 1)$, so that it unequivocally reduces transparency. The qualitative analysis in that case is likely to be very similar to the one we conducted. If $\delta > 2$, in turn, inequality raises both majoritarian taxes and $t^*(0, 1)$. By continuity, it seems that the qualitative results of our present analysis should extend to that case, at least as long as δ is not too high. For very high values of δ , in turn, we expect that, coherently with the result in Proposition 6, inequality favors transparency even when the endogeneity of majoritarian taxes is taken into account. Indeed, as $\delta \rightarrow \infty$, labor supply becomes perfectly rigid, the tax distortion disappears and the government has no incentive whatsoever to manipulate information.

³⁴Recall that, by Proposition 6, for $\delta = 2$ such range is independent of inequality.

5 Comments and implications

We now take stock of our results and discuss a number of implications.

- Governments tend to truthfully reveal information when tax distortions are low. This is a direct implication of Proposition 2 and it clearly follows from the fact that, as is usual in second best environments, an additional distortion (here, hiding information in recessions) can be used to correct for an existing one. Specifically, when tax distortions are high, governments have an incentive to cheat in recessions, in order to stimulate labor supply and compensate for its suboptimal level; yet, by so doing, they lose credibility. When tax distortions are low, hiding information about a recession induces (suboptimal) overwork. If taxes are low enough, in recessions the welfare costs of overwork under information hiding are higher than the costs of underwork under information revelation. So for low taxes, governments have an incentive to reveal information, thus gaining credibility.
- All else equal, governments tend to reveal information when aggregate shocks are big, whereas they tend to hide information when shocks are small. The intuition is exactly the same as for the effects of tax distortions, since what matters is the relative magnitude of the underwork distortion caused by taxes and the information distortion caused by cheating in recessions. Small shocks mean that, by hiding information about a recession, the government provides just a small stimulus to labor supply. With positive taxes, and therefore with under-supply of labor, it is always the case that a sufficiently small increase in labor supply raises welfare. In turn, when aggregate shocks are big, hiding information about a recession provides a powerful stimulus to labor supply. If the shock is big enough, this generates overwork, whose welfare costs increase in the magnitude of the shock and eventually become bigger than the costs of underwork under information revelation.
- Inequality in pre-tax income distribution has both a direct and an indirect effect on transparency. The direct effect is obtained holding fixed the tax rate, whereas the indirect one works through changes in the tax rate. According to the direct effect, inequality favors transparency when labor supply is rigid, has the opposite effect when it is elastic (at least for a substantial range elasticities), and is irrelevant

for transparency when labor supply is linear. Much of the literature on government information transparency assumes a linear labor supply, thus assuming away the effects of inequality. In contrast, our results show that, for plausible values of labor supply elasticity, in recessions an increase in inequality raises welfare faster under transparency than under information hiding, so that, when we look at the direct effect alone, transparency and inequality tend to be complements.

- Yet, if inequality is also associated to higher tax rates, the result might be reversed. When we close the model with an endogenous determination of the tax rate, we show that the median voter selects higher taxes, the higher the level of inequality. So the indirect effect of inequality is that it reduces transparency. Combined with the previous results, this tells us that inequality unequivocally reduces transparency under either linear or elastic labor supply, whereas it generates two contrasting forces under the more plausible case of rigid labor supply: while it provides a direct incentive for transparency, it also raises taxes, which provides the opposite incentive. The overall result is hard to establish in general terms. Beyond the median voter model, if the tax determination process is little sensitive to inequality, we should expect inequality and transparency to be positively correlated, whereas if the reverse is true, they are likely to be negatively correlated.
- An empirical implication of our model is that, all else equal, output and hours worked fluctuate more when the government is transparent. This is consistent with the evidence provided by Demertzis and Hughes-Hallett (2007). At the same time, the government tends to be transparent when aggregate shocks are relatively small. This means that it is not immediate to predict whether, in absolute terms (i.e., forgetting about the *ceteris paribus* condition), the magnitude of fluctuations should be positively or negatively correlated with government's information transparency.
- Insofar as output volatility is higher in an informative equilibrium and transparency is more likely for lower taxes, our model offers a possible explanation for the recently uncovered negative relationship between taxation and output volatility (Debrun et al., 2008).
- Another empirical implication is that we should expect credibility and

reliability of government's information to be higher in those countries that exhibit low taxes, high aggregate shocks and high inequality (at least to the extent that taxes are not very responsive to inequality). Examples might include governments in small open economies, which are typically hit by bigger shocks, governments in periods of high fluctuations (e.g., the present global crisis), and governments in countries with a rather unequal distribution of human capital (e.g., the U.S.). Yet, rather than to explain individual cases, our contribution is designed to highlight the working of a few (relevant and new) theoretical mechanisms, which empirical investigations of the determinants of transparent government communication should keep in mind.

- A note of caution for empirical work on government communication is that we show that transparency is ex-ante Pareto dominant. So, although it is not an equilibrium when tax distortions are relatively high, governments might still find a way to tie their hands and commit to transparency, for instance through an appropriate design of independent statistical institutes.
- From the theoretical point of view, observe that precisely when the government lies, individuals are ex post happy that it lied. Therefore, the fact that the government's private information is ex post verifiable poses no problems of possible continuations of the game in which lies are sanctioned.
- Our theory highlights the limits of equilibrium transparency when the government is benevolent, individuals are rational and no credible commitment is possible. In particular, it shows that transparency is not an equilibrium when tax distortions are high. Let us now discuss a few possible extensions, which we leave for future research. It would be interesting to investigate the interaction of opportunistic and benevolent motives on the side of government. For instance, an incumbent government might want to be over-optimistic to influence individuals' beliefs on its ability, beyond the motive emphasized in this paper. While this would provide an extra incentive to hide bad news, we expect that it would not change our main results.
- While we have enriched the standard cheap talk game with a continuum of receivers, we have simplified its state and message space to just two

values. An extension to the continuum case would allow to analyze the degree of precision of the information transmitted by the government. While this may be an interesting extension, we feel that the simple case of two states and messages is better suited to convey our main intuition in a clear way.

- Observe that the main message of the paper goes well beyond the specific application we study. First, one can imagine different mechanisms of tax determination, without affecting the results of the first part of the paper. Second, the general idea that the a benevolent government may manipulate information to undo an existing distortion can be readily applied to any kind of distortion, and not just to income taxation. Third, the argument extends to any principal-agent problem, in which the principal has private information on the relation between individual actions and results and can manipulate it to counterbalance the agent's suboptimal behavior.

6 Conclusion

This paper studies a model of government announcements about the future state of economic activity. We find conditions for the emergence of informative and non-informative government communication regimes in an economy characterized by persistent distortions and government private information.

The basic message of this paper is twofold. First, even a benevolent government may be non-informative in an attempt to undo sufficiently high distortions and induce higher labor supply. This casts doubts on the commonsense view according to which the lack of government information transparency is simply a consequence of bad or corrupt bureaucrats. Second, we show that the informative equilibrium outcome is ex ante Pareto-dominant. This result suggests that in the presence of unremovable distortions, governments should commit to truthful communication. This provides a rationale for independent national statistical offices.

We show that transparency is negatively associated with the extent of distortions, while it is strengthened by the magnitude of shocks suffered by the economy. Last, given tax rates, inequality has a direct effect on government transparency, which is positive or negative depending on labor supply elasticity. Yet, to the extent that inequality generates higher tax rates

and therefore higher distortions, it also has an indirect effect, which reduces transparency.

Appendices

A Convexity/concavity of $z(\beta)$

Lemma 4 (Convexity/concavity of $z(\beta)$)

For any $t \in (0, 1)$, the function of β

$$z(\beta) = \frac{1-t}{\delta} \left[(\beta + \vartheta)^{\frac{\delta}{\delta-1}} - (\beta - \vartheta)^{\frac{\delta}{\delta-1}} \right] - (\beta - \vartheta) \left[(\beta + \vartheta)^{\frac{1}{\delta-1}} - (\beta - \vartheta)^{\frac{1}{\delta-1}} \right]$$

is linear for $\delta = 2$, strictly convex for $\delta > 2$ and strictly concave for $\delta \in \left[\frac{3-t}{2}, 2 \right)$.

Proof The first and second derivative of $z(\beta)$ at a generic $t \in (0, 1)$ are

$$\begin{aligned} z'(\beta) &= \frac{1}{(\delta-1)} \left\{ (2-\delta-t) \left[(\beta + \vartheta)^{\frac{1}{\delta-1}} - (\beta - \vartheta)^{\frac{1}{\delta-1}} \right] + \right. \\ &\quad \left. - (\beta - \vartheta) \left[(\beta + \vartheta)^{\frac{2-\delta}{\delta-1}} - (\beta - \vartheta)^{\frac{2-\delta}{\delta-1}} \right] \right\}, \\ z''(\beta) &= \frac{1}{(\delta-1)^2} \left\{ (3-2\delta-t) \left[(\beta + \vartheta)^{\frac{2-\delta}{\delta-1}} - (\beta - \vartheta)^{\frac{2-\delta}{\delta-1}} \right] + \right. \\ &\quad \left. - (2-\delta)(\beta - \vartheta) \left[(\beta + \vartheta)^{\frac{3-2\delta}{\delta-1}} - (\beta - \vartheta)^{\frac{3-2\delta}{\delta-1}} \right] \right\}. \end{aligned}$$

For $\delta = 2$, $z''(\beta) = 0$ for any $t \in (0, 1)$, so $z(\beta)$ is linear.

For $\delta = \frac{3}{2}$, $z''(\beta) < 0$ for any $t \in (0, 1)$, so $z(\beta)$ is concave.

For $\delta \neq 2, \delta \neq \frac{3}{2}$, we can re-write

$$\begin{aligned} z''(\beta) &= \frac{(2-\delta)}{(\delta-1)^2} \left[(\beta + \vartheta)^{\frac{3-2\delta}{\delta-1}} - (\beta - \vartheta)^{\frac{3-2\delta}{\delta-1}} \right] \cdot \\ &\quad \cdot \left\{ \frac{(3-2\delta-t) \left[(\beta + \vartheta)^{\frac{2-\delta}{\delta-1}} - (\beta - \vartheta)^{\frac{2-\delta}{\delta-1}} \right]}{(2-\delta) \left[(\beta + \vartheta)^{\frac{3-2\delta}{\delta-1}} - (\beta - \vartheta)^{\frac{3-2\delta}{\delta-1}} \right]} - (\beta - \vartheta) \right\} \end{aligned}$$

and study the three sub-cases $\delta > 2$, $\delta \in \left(\frac{3}{2}, 2 \right)$, $\delta \in \left(1, \frac{3}{2} \right)$.

For $\delta > 2$, the sign of $z''(\beta)$ is the same as the sign of the term in curly brackets. Let $a_0 = (\beta - \vartheta)^{\frac{3-2\delta}{\delta-1}}$ and $a_1 = (\beta + \vartheta)^{\frac{3-2\delta}{\delta-1}}$, notice that $a_0 > a_1$ and consider the function $g(a) = \left(\frac{3-2\delta}{2-\delta}\right) a^{\frac{2-\delta}{3-2\delta}}$. Since it is concave, we have $\frac{g(a_0)-g(a_1)}{a_0-a_1} > g'(a_0) = (\beta - \vartheta)$. The left hand side in this inequality is the first term in the curly brackets for $t = 0$, so that we have $z''(\beta) > 0$ for $t = 0$. Since $\frac{\partial z''(\beta)}{\partial t} > 0$, we have that for any $t \in (0, 1)$, $z''(\beta) > 0$.

For $\delta \in \left(\frac{3}{2}, 2\right)$, the sign of $z''(\beta)$ is opposite to the sign of the term in curly brackets. We have $\frac{2-\delta}{3-2\delta} < 0$, so $g(a)$ is again concave, and again $a_0 > a_1$. So $\frac{g(a_0)-g(a_1)}{a_0-a_1} > g'(a_0) = (\beta - \vartheta)$ and $z''(\beta) < 0$ for $t = 0$. Since $\frac{\partial z''(\beta)}{\partial t} < 0$, we have that for any $t \in (0, 1)$, $z''(\beta) < 0$.

For $\delta \in \left(1, \frac{3}{2}\right)$, using the fact that $(\beta + \vartheta)^{\frac{2-\delta}{\delta-1}} = (\beta + \vartheta)(\beta + \vartheta)^{\frac{3-2\delta}{\delta-1}}$ and $(\beta - \vartheta)^{\frac{2-\delta}{\delta-1}} = (\beta - \vartheta)(\beta - \vartheta)^{\frac{3-2\delta}{\delta-1}}$, and rearranging, we can write $z''(\beta) = \frac{1}{(\delta-1)^2} \left[A(\beta - \vartheta)^{\frac{3-2\delta}{\delta-1}} - B(\beta + \vartheta)^{\frac{3-2\delta}{\delta-1}} \right]$, where $A \equiv (\delta + t - 1)(\beta - \vartheta)$ and $B \equiv (\delta + t - 1)\beta + (3\delta + t - 5)\vartheta = A + 2(2\delta + t - 3)\vartheta$. Since $\delta \in \left(1, \frac{3}{2}\right)$ implies that $(\beta - \vartheta)^{\frac{3-2\delta}{\delta-1}} < (\beta + \vartheta)^{\frac{3-2\delta}{\delta-1}}$, and $B > A \iff 2\delta + t > 3$, we have that a sufficient condition for $z''(\beta) < 0$ is $\frac{3-t}{2} \leq \delta < \frac{3}{2}$. ■

B Linear and quadratic labor supply

In this appendix we develop two specific examples, corresponding to the special cases of linear and quadratic labor supply. For $\delta = 2$, labor supply is linear. Its wage elasticity, equal to 1, is in the upper range of most microeconomic estimates. For $\delta = \frac{3}{2}$, labor supply is quadratic. Its wage elasticity, equal to 2, is above most microeconomic estimates. For these two cases, expression (3) simplifies considerably, since the ability distribution F influences (3) only through its first two moments, $E(\beta)$ and $V(\beta)$. Recall that we call $\epsilon \equiv \frac{\vartheta}{E(\beta)}$ the relative importance of the aggregate shock and now denote by $\eta \equiv 1 + v = \frac{E(\beta^2)}{[E(\beta)]^2} = \frac{[E(\beta)]^2 + V(\beta)}{[E(\beta)]^2}$ the pre-tax wage dispersion.

We prove first in Lemma 5 a monotonicity result for $t^*(\mu, \nu)$, which grants existence of non babbling equilibria at any tax rate. Its implications are drawn in Corollary 1.³⁵ Remark 11 explicitly computes the relevant thresh-

³⁵Numerical investigation, discussed in Appendix C, shows that Lemma 5 and Corollary 1 generalize to a great number of parameter constellations and distributional assumptions.

olds for non babbling equilibria.

Lemma 5 (Monotonicity of $t^*(\mu, \nu)$ for $\delta = 2$ and $\delta = \frac{3}{2}$)

If either $\delta = 2$ or $\delta = \frac{3}{2}$, then for any constellation of other parameters, any ability distribution with finite mean and variance,³⁶ and any values of μ and ν such that $0 \leq \mu < \nu \leq 1$,

$$\frac{\partial t^*(\mu, \nu)}{\partial \mu} > 0, \quad \frac{\partial t^*(\mu, \nu)}{\partial \nu} > 0.$$

Proof First observe that $\epsilon \in (0, 1)$, due to $0 < \vartheta < b$, and that $\eta > 1$. For $\delta = 2$ and $\delta = \frac{3}{2}$, expression (3) becomes $t^*(\mu, \nu) = t_L^*(\mu, \nu)$ and $t^*(\mu, \nu) = t_Q^*(\mu, \nu)$, respectively, where

$$t_L^*(\mu, \nu) = \frac{(\mu + \nu)\vartheta}{(\mu + \nu)\vartheta + E(\beta) - \vartheta} = \frac{(\mu + \nu)\epsilon}{(\mu + \nu)\epsilon + (1 - \epsilon)}. \quad (4)$$

$$t_Q^*(\mu, \nu) = \frac{\epsilon(\mu + \nu) + \epsilon^2 \left[\frac{4}{3}(\nu - \mu)^2 + 4\mu\nu - (\mu + \nu) \right]}{\eta + 2\epsilon(\mu + \nu - 1) + \epsilon^2 \left[\frac{4}{3}(\nu - \mu)^2 + 4\mu\nu - 2(\mu + \nu) + 1 \right]}. \quad (5)$$

For $\delta = 2$, both results are immediate to obtain from (4).

Now let $\delta = \frac{3}{2}$ and call D the denominator in (5). Explicit calculation yields that $\frac{\partial t^*(\mu, \nu)}{\partial \mu}$ and $\frac{\partial t^*(\mu, \nu)}{\partial \nu}$ are respectively equal to the following expressions:
 $D^{-2} \cdot \left\{ \epsilon \left[1 + \epsilon \left(\frac{8}{3}\mu + \frac{4}{3}\nu - 1 \right) \right] \cdot [(\eta - 1) + (1 - \epsilon)^2] + \frac{4}{3}\mu(\mu + 2\nu)\epsilon^3(1 - \epsilon) \right\};$
 $D^{-2} \cdot \left\{ \epsilon \left[1 + \epsilon \left(\frac{8}{3}\nu + \frac{4}{3}\mu - 1 \right) \right] \cdot [(\eta - 1) + (1 - \epsilon)^2] + \frac{4}{3}\nu(\nu + 2\mu)\epsilon^3(1 - \epsilon) \right\}.$
 $\frac{\partial t^*(\mu, \nu)}{\partial \mu} > 0$ and $\frac{\partial t^*(\mu, \nu)}{\partial \nu} > 0$ then follow from $\epsilon \in (0, 1)$ and $\eta > 1$. ■

Corollary 1 (Non babbling equilibria for $\delta = 2$ and $\delta = \frac{3}{2}$)

If either $\delta = 2$ or $\delta = \frac{3}{2}$, then there exist three non empty tax intervals, such that the following holds for non babbling equilibria.

- For $t \in (0, t^*(0, p))$, only the separating equilibrium exists.
- For $t \in [t^*(0, p), t^*(0, 1)]$, both the separating and the pooling equilibrium exist. Moreover, a semi-separating equilibrium exists if and only if $t = t^* \left(0, \frac{p}{p + (1-p)\rho} \right)$.

³⁶For $\delta = 2$ (but not for $\delta = \frac{3}{2}$) the result also extends to distributions with infinite variance.

- For $t \in (t^*(0, 1), 1)$, only the pooling equilibrium exists.

Proof The result is a corollary of Proposition 2 and Lemma 5, since $\forall p \in (0, 1), \forall \rho \in (0, 1), t^*(0, p) < t^*\left(0, \frac{p}{p+(1-p)\rho}\right) < t^*(0, 1)$. Observe that we focus here on the pooling equilibrium with $\mu = 0$, because Lemma 5 implies that, given $p \in (0, 1)$ and either $\delta = 2$ or $\delta = \frac{3}{2}$, for any $t \geq t^*(0, p)$ we can find beliefs $\mu \in [0, p)$ sufficiently low to sustain a pooling equilibrium.³⁷ ■

Remark 11 ($t^*(0, p)$ and $t^*(0, 1)$ for $\delta = 2$ and $\delta = \frac{3}{2}$)

From equations (4) and (5), the relevant thresholds in Corollary 1 are:

$$\begin{aligned} \delta = 2 : \quad t_L^*(0, p) &= \frac{p\epsilon}{p\epsilon + (1 - \epsilon)}, & t_L^*(0, 1) &= \epsilon, \\ \delta = \frac{3}{2} : \quad t_Q^*(0, p) &= \frac{(4p^2 - 3p)\epsilon^2 + 3p\epsilon}{(4p^2 - 6p + 3)\epsilon^2 - 6(1 - p)\epsilon + 3\eta}, & t_Q^*(0, 1) &= \frac{\epsilon^2 + 3\epsilon}{\epsilon^2 + 3\eta}. \end{aligned}$$

Proposition 3 implies that, whenever it exists, the separating equilibrium ex ante Pareto dominates any other equilibrium.³⁸ Remark 3 and Lemma 5 imply that any equilibrium satisfies NITS, with the exception of babbling equilibria for $t < t^*(0, p)$; and Proposition 4 implies that the separating

³⁷Indeed, when an L message is interpreted as a sure signal that the true state of the world is a recession, i.e., $\mu = 0$, existence chances for a pooling equilibrium are highest.

³⁸Explicit calculation yields the following welfare levels. Let $\bar{\theta} = p\vartheta - (1 - p)\vartheta$ be the expected value of θ according to prior beliefs. Denote ex ante social welfare in the separating and in the pooling equilibrium as W_L^S and W_L^P , respectively, for $\delta = 2$, and as W_Q^S and W_Q^P , respectively, for $\delta = \frac{3}{2}$. We then have

$$\begin{aligned} W_L^S &= \frac{1 - t^2}{2} \left\{ V(\beta) + [E(\beta) - \vartheta]^2 + 4p\vartheta E(\beta) \right\}, \\ W_L^P &= \frac{1 - t^2}{2} \left\{ V(\beta) + [E(\beta) + \bar{\theta}]^2 \right\}, \\ W_Q^S &= \frac{1}{3}(1 - t)^2(1 + 2t) \int_b^B [(1 - p)(\beta - \vartheta)^3 + p(\beta + \vartheta)^3] dF(\beta), \\ W_Q^P &= \frac{1}{3}(1 - t)^2(1 + 2t) \int_b^B (\beta + \bar{\theta})^3 dF(\beta). \end{aligned}$$

equilibrium is the only Neologism Proof equilibrium, so that we should expect it whenever it exists. Therefore, government information transparency should be expected in equilibrium when $t \leq t^*(0, 1)$. From Remark 11, we have that the relevant threshold for transparency is $t^*(0, 1) = t_L^*(0, 1)$ and $t^*(0, 1) = t_Q^*(0, 1)$, in the case of linear and quadratic labor supply, respectively, where

$$\begin{aligned} t_L^*(0, 1) &= \epsilon, \\ t_Q^*(0, 1) &= \frac{\epsilon^2 + 3\epsilon}{\epsilon^2 + 3\eta}. \end{aligned}$$

The comparative statics implications of Propositions 5 and 6, namely that shock magnitude always favors transparency, whereas inequality is irrelevant under linear labor supply and makes governments less reliable under quadratic labor supply, can then be grasped by observing that $\frac{\partial t_L^*(0,1)}{\partial \epsilon} > 0$, $\frac{\partial t_Q^*(0,1)}{\partial \epsilon} > 0$, $\frac{\partial t_L^*(0,1)}{\partial \eta} = 0$ and $\frac{\partial t_Q^*(0,1)}{\partial \eta} < 0$.

C Monotonicity of $t^*(\mu, \nu)$

Although we cannot offer a general analytical proof of the fact that, for any parametric and distributional assumption, and for any μ and ν such that $0 \leq \mu < \nu \leq 1$, it holds that $t^*(\mu, \nu)$ is strictly increasing in its arguments, we have nevertheless performed a series of numerical simulations, which show that the results in Lemma 5 hold for a great variety of parameter constellations and distributional assumptions, much beyond the specific assumptions stated there. Figure 3 illustrates some of our numerical simulations. Each quadrant plots $t^*(\mu, \nu)$ against μ in the range $0 \leq \mu < \nu \leq 1$, for different values of ν . In all quadrants $\vartheta = 0.5$. Rows correspond to different values of δ , between 2 and 4, amounting to plausible values of labor supply elasticity. Columns correspond to different skill distributions, with low inequality on the left and high inequality (and infinite variance) on the right.³⁹ It can be seen that in all cases $t^*(\mu, \nu)$ is strictly increasing in both arguments for $0 \leq \mu < \nu \leq 1$. Further simulations, not reported, show that this result also extends to other parametric and distributional assumptions.

³⁹Both columns are drawn for a Pareto distribution with scale parameter 1. The shape parameter is equal to 3 on the left, implying a Gini index $G = 0.2$, and it is equal to $4/3$ on the right, implying a Gini index $G = 0.6$, roughly the value of the U.S. income distribution. Mean and variance of the skill distribution are equal to 1.5 and 0.375, respectively, on the left, and to 4 and ∞ , respectively, on the right.

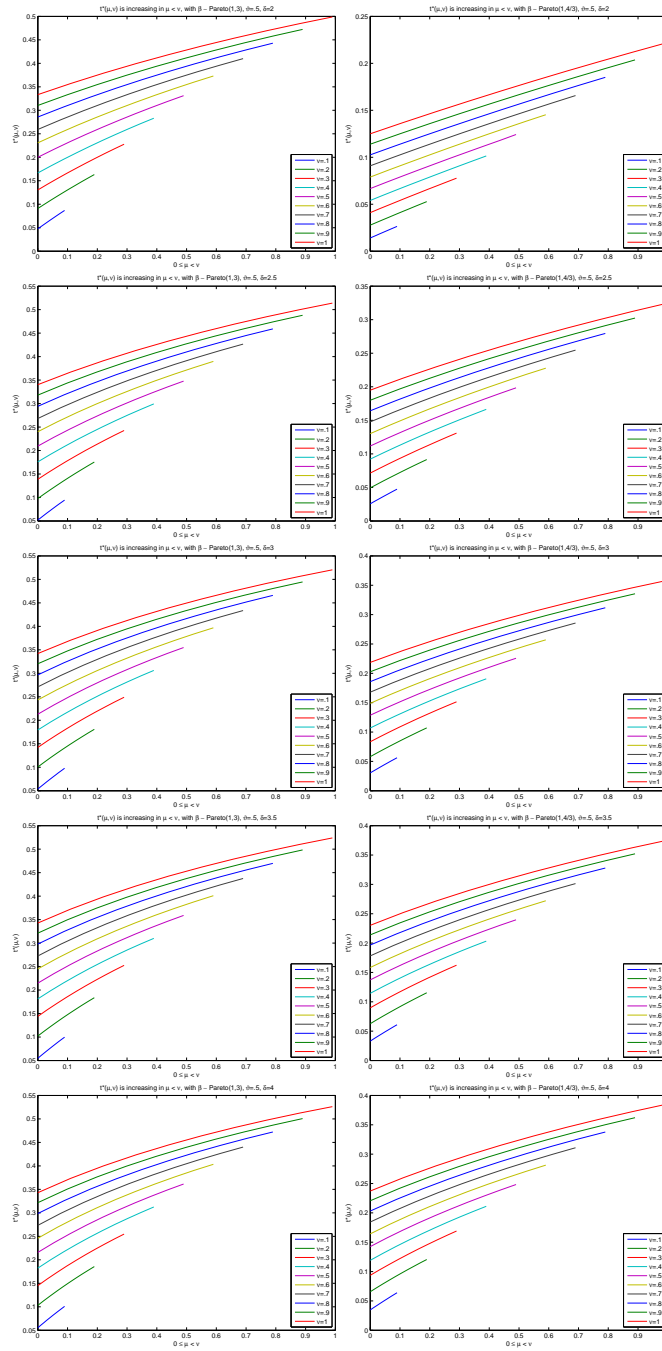


Figure 3: Monotonicity of $t^*(\mu, \nu)$ in both arguments for $0 \leq \mu < \nu \leq 1$.

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