Strategic Information Transmission by a Policymaker Targeting Aggregate Activity

Jochen F Schanz[1]

This version: July 9, 2003

Keywords: signalling, transparency, disclosure. **JEL**: C72, D82, E61

Abstract.

This paper starts from the stylised fact that policymakers publish their information only selectively: a central bank tends not to predict a recession and the IMF is unlikely to forecast a currency crisis. The paper, then, searches for the circumstances in which such a partially-revealing reporting rule is part of an (sequential) equilibrium within a static signalling game in which market participants (the receivers) take the policymaker's reporting strategy into account when evaluating his report.

With the aim of explicitly linking the policymaker's target function to social welfare, the economic framework in which partially-revealing reporting rules are analysed is a partial equilibrium model of an imperfectly competitive economy in which firms Cournot-compete for customers when demand is uncertain. To circumvent full revelation results obtained in the literature, it is assumed that the policymaker fears that markets would overreact to such information if it were published.

Results available so far suggest that the equilibrium reporting rule has the following properties: extreme news is withheld and intermediate news published. In addition, the higher the policymaker's incentive to increase production (i.e., the less competitive the economy is), the worse the worst news he makes public; likewise, the better the best news he makes public; the lower the market's expectation of his information if he withholds; and the better the average news he publishes.

"One reason that the WEO [World Economic Outlook] does not predict crises is that, if it did, these predictions could be self-fulfilling - which would improve our apparent accuracy, but would clearly be irresponsible. Given our responsibilities for global financial stability, we are instead looking for better ways to use our analysis to motivate vulnerable countries to make policy changes that can help head off crises - even if this make our predictions appear less accurate."

Anne Krueger, First Deputy Managing Director at the IMF, in response to criticism that the IMF's forecasts fail to predict many currency crises.[2]

1 Introduction

The aim of this paper is to find circumstances in which a publication policy (a reporting rule) as sketched by Ms. Krueger can be described as equilibrium behaviour of a signalling game. Throughout the paper, it is assumed that messages are verifiable: The policymaker cannot publish a biased account of his research. If he does not want to publish it, his only other option is to withhold the research results.

If the sender's preferences are monotonic in the receiver's action, the sender fully discloses his type in every sequential equilibrium of a Sender-Receiver game with verifiable messages (cf. Milgrom (1981)). Thus, if the IMF's only aim is to prevent currency crises, and currency crises become more likely the worse the economic news about a country, a static framework in which the policymaker withholds only very bad information cannot explain Anne Krueger's statement as describing a (sequential) equilibrium strategy.

Now suppose instead that the sender's preferences are concave in the receiver's actions. This could describe a world in which the IMF has a target level of foreign direct investment, depending on the economic information it has received about the country:

It neither wants capital markets to flush a country with funds, nor to withdraw them completely. However, it wants capital markets to invest more in a country whose economic fundamentals are better. As long as the sender's preferred action is higher for all types, or lower for all types, than the receiver's preferred action, Seidmann and Winter (1997) show that a sequential equilibrium in which the sender fully discloses his type exists and is, in many circumstances, also unique.

A situation in which the sender does not fully disclose his type is characterised by a certain behaviour of the sender's and the receiver's preferred action (which is a function of the sender's type). Specifically, if the sender prefers a higher action than the receiver when he is of the lowest type, and a lower action than the receiver when he is of the highest type, Seidmann and Winter (1997)'s uniqueness proof does not apply. In the IMF's case this could be interpreted as a situation in which the IMF is worried that the market might overreact to a piece of economic news: It fears a currency attack when economic fundamentals are bad, but is equally worried about overinvestment when economic fundamentals are good. In this case, an equilibrium can exist in which extreme news is withheld. That is, the IMF finds it optimal to withhold very good and very bad news, and publish intermediate news.

With the aim to explicitly link the policymaker's target function to social welfare, the following sections depart from the case of the IMF and consider instead a partial-equilibrium model of oligopolistic competition, in which welfare is easily defined as the sum of consumer surplus and firms' profits. Section 2 sets up the basic model in which both sender and receiver have concave preferences in their actions. Subsection 2.4 provides some intuition for Seidmann and Winter's result that the unique sequential equilibrium has to lead to full disclosure in this context. Section 3 then considers the case in which the policymaker is worried that market participants might overreact to his private information, once it is made public. This assumption is justified in subsection 3.1. Results on the form of the equilibrium reporting rule are presented in subsection 3.3. Section 4 discusses the results and potential extensions.

2 Formalisation

2.1 Type of game; timing; and equilibrium concept

The game is a game of strategic information transmission as described by Milgrom (1981) and Crawford and Sobel (1982) between a policymaker (the sender) and firms (the receivers). All agents are uncertain about the demand firms will face and share a common prior about its distribution.[3] Only the policymaker receives private information about the demand. Firms maximise their profits by Cournot-competing for customers. The policymaker chooses a whether to publish or withhold his information, with the aim to maximise social welfare. Finally, it is assumed that players coordinate on the equilibrium reporting rule which leads to the highest social welfare.

The game proceeds as follows:[4]

1. Nature chooses the realisation a of the intercept A of the linear demand schedule firms will be facing, and the policymaker's type t. A is uniformly distributed on $\Omega = [\alpha, \beta]$; the policymaker's type has a continuous distribution with the same support. The correlation between policymaker's type and the demand intercept is weakly positive.

2. The policymaker observes his type $t \in \Omega$ and then makes a report s to the firms. A report s is a closed nonempty subset of Ω, interpreted as the policymaker's assertion that $t \in s$. A reporting strategy $r(t)$ is a function from Ω to the set of closed nonempty subsets of Ω with the property that $t \in r(t)$. That is, the policymaker's report can be very vague ($r(t) = \Omega$) or very precise ($r(t) = t$), but never false. To facilitate the analysis, it is assumed that $r(t) \in \{\{t\}, \Omega\}$ for all t. If $r(t) = \{t\}$, it is said that "the policymaker publishes his information". If, instead, $r(t) = \Omega$, it is said that "the policymaker withholds his information".

3. F firms evaluate the report, attempting to infer the policymakers type, which con-

---

[3]See Vives (1999), ch. 8, for a review of models of oligopolistic competition with uncertain demand.

[4]This is directly adapted from Milgrom (1981)'s example of a "persuasion game".

tains information about future demand. Given a report s, let $i_f(s)$ be a nonempty subset of s representing firm f's inference drawn from the policymaker's report. The interpretation is that if the policymaker reports s, firm f infers that $t \in i_f(s)$. Firms then simultaneously decide on their production capacity, a real-valued positive number. Firm f's capacity strategy $q_f^c(s)$ is a function from reports to capacity decisions.

4. Finally, firms observe the realisation a of the demand intercept A and Bertrand-compete under the capacity limits.

The solution concept is a sequential equilibrium in pure strategies. That is,

1. For all firms f and every possible[5] report s, $q_f^c(s)$ maximises firm f's expected profit.

2. For all types t, report $r(t)$ maximises the policymaker's target function (social welfare).

3. For all reports s in the range of r, $i_f(s) = r^{-1}(s)$. That is, the firms' inferences are consistent with the policymaker's strategy: They take the policymaker's intentions into account when evaluating his report.

The following definition, adapted from Milgrom (1981), will be needed:

Definition 1 *A reporting strategy is called "fully revealing" if the reporting strategy r together with any optimal response $\left\{ \left(q_f^c, i_f \right) \right\}_{f=1}^{F}$ satisfies $q_f^c(r(t)) = q_f^c(\{t\})$ for all f.*

Intuitively, a strategy of full disclosure does not conceal any information relevant to the firms. Strategies that do not fully disclose the policymaker's type are called "partially revealing".

---

[5]This excludes equilibria of the type "firms always ignore the policymaker's report, and the policymaker always reports Ω", which do not seem to have descriptive content for the problem under consideration.

2.2 The economic environment

The economic environment is a standard two-stage game of oligopolistic competition, in which firms first choose their capacity and subsequently Bertrand-compete for customers. In the first stage, F firms simultaneously decide about the level of capacity they want to build for a constant marginal cost $c < \alpha$. (This restriction ensures that in equilibrium, desired capacity will be positive for all signal realisations.) In the second stage, they produce the same good under these capacity limits and Bertrand-compete for customers, facing the linear demand schedule $p = a - \sum q_f$. The unique equilibrium of the second stage involves firms setting prices equal to $p = a - \sum q_f^c$ where q_f^c is the capacity provided by firm f in the first stage. Thus, in the first stage, when the realisation a of the intercept A is still unknown, firm f solves $\max_{q_f^c} \left\{ E \left[\left(A - \sum_{i=1}^{F} q_i^c - c \right) q_f^c | s \right] \right\}$ which leads to the optimal capacity choice of $q_f^c(s) = q^c(s) = \frac{1}{F+1} (E[A|s] - c)$ and aggregate capacity of

$$Q^* = \frac{F}{F+1} (E[A|s] - c) \tag{1}$$

(Recall that s is the report the firms receive from the policymaker.)

2.3 Welfare

If firms underestimate demand in the first stage, there will be excess capacity in the second stage. In this case, the usual Bertrand-equilibrium obtains in which prices equal marginal cost of production. These are assumed to be zero; thus equilibrium aggregate production equals the demand intercept. In this case, firms cannot recover the costs of building up capacity in the first stage and welfare is - recall that quasi-linear preferences are assumed - $W = \frac{1}{2}a^2 - cQ$. If, in contrast, the capacity constraints are binding, welfare is $W = \frac{1}{2}Q^2 + Q(a - Q) - cQ$ where the first term is consumer surplus, the second firms' revenues, and the third total costs of building capacity. Simplifying yields

$$W = -cQ + \begin{cases} \frac{1}{2}Q(2a - Q) & \text{if } Q \leq a \\ \frac{1}{2}a^2 & \text{if } Q > a \end{cases} \tag{2}$$

Notice that the preferences of the sender are not monotone in the actions of the receiver. Instead, for a given demand a, increasing capacity increases total welfare until

the market price falls below the marginal costs c of building capacity. Welfare is concave in Q ($\frac{\partial^2 W}{\partial Q^2} \leq 0$), and thus, it is strictly falling in the difference of targeted production $\hat{Q}$ from actual production Q. It reaches its maximum when prices equal marginal costs, which is the case for

$$\hat{Q} \equiv a - c \tag{3}$$

The following definition relates to the game under certainty ($E[A] = a$) and will be used to characterise comparative static results in section 3.4.6:

Definition 2 *The policymaker's incentive to increase output is defined as the marginal increase in welfare an increase in production causes at Q^**

$$\frac{\partial W}{\partial Q}_{|Q=Q^*} = -c + \begin{cases} a - Q^* & \text{if } Q^* \leq a \\ 0 & \text{if } Q^* > a \end{cases} \tag{4}$$
$$= \frac{a - c}{F + 1}$$

where the last equality follows from $Q^* \leq a$ for all parameter values, and Q^* is given by (1).

That is, the incentive to increase production is falling the more competitive the economy becomes, and the higher the costs of building capacity.

2.4 The unique sequential equilibrium is fully revealing.

This result follows directly from Seidmann and Winter (1997). (The appendix checks that the conditions are fulfilled.) Key to its understanding is that as long as the economy is imperfectly competitive (finite F), each type has an incentive to increase output (cf. definition 2) Clearly, a reporting strategy that prescribes withholding only for the highest type is not part of an equilibrium: Each type in a non-empty set of types just below the highest type would then have an incentive to switch to "withhold". Thus, firms' mean estimate of the policymaker's type will lie strictly below the highest type after receiving $s = \Omega$. Consequently, the highest type has a strict preference for publishing. Given that he publishes, a corresponding argument can be made for the second-highest type, and

further down to the lowest type who is the only type indifferent between publishing and withholding. But even if he withholds, firms' inference will be that he is the lowest type. Thus, the equilibrium is fully revealing.

3   Agents agree to disagree about the informational content of the signal.

A necessary condition for Seidmann and Winter (1997)'s uniqueness result is that, when moving from the lowest to the highest sender type, the difference between the receiver's and the sender's preferred action either does not change sign, or is positive for the lowest type and only changes sign once. Thus, to justify that withholding information can be an equilibrium outcome, one can look for situations in which these conditions are both violated. In the present framework, a realistic situation in which these conditions are both violated occurs when the receiver puts more emphasis on the signal than the sender.

3.1   Justification

Situations in which economic agents agree to disagree on certain parameters of the economic environment have been explored in the literature. In Harris and Raviv (1993), traders share a common prior about the profitability of an investment, but do not share the same interpretation of a public signal that is correlated with the profitability of the investment opportunity. This assumption enables the authors to explain certain time-series properties of financial data. Harrison and Kreps (1978) show that if rational investors disagree about the interpretation of publicly available information, in equilibrium, the asset price can rise above the expectation of the fundamental value of even the most optimistic group of investors.

The specific type of disagreement - firms put more emphasis on the policymaker's private information than the policymaker himself - also appears justifiable. Empirically, central banks appear often worried that markets overreact to public information. In December 1996, Alan Greenspan, Chairman of the Board of Governors of the US Federal

Reserve System, warned investors of irrational exuberance when analysing the (public) information they had about stock prices.[6] In June 2000, Willem F. Duisenberg, President of the European Central Bank, said that he considered the euro was out of line with fundamentals, implying that it was undervalued.[7] In November 2002, Mervyn King, Deputy Governor of the Bank of England, issued the starkest warning so far about the negative consequences of the UK house price inflation.[8] In all these cases, policymakers were worried that market participants had misjudged the public information that was available. Recall that this paper attempts to justify a policymaker's reporting rule that prescribes to withhold information for some values. Thus, as long as one refrains from ranking equilibria according to actual welfare, as opposed to the policymaker's estimate of welfare, it is immaterial whether market participants do overreact to public information, or whether policymakers just perceive the market to overreact.[9]

With the aim to solve explicitly for the policymaker's reporting rule, the following section considers a stylised, extreme case. In particular, it is assumed that it is commonly known that the policymaker attaches no importance to the information he receives, but that firms believe it is very informative.

---

[6]"Remarks by Chairman Alan Greenspan At the Annual Dinner and Francis Boyer Lecture of The American Enterprise Institute for Public Policy Research", Washington, D.C., December 5, 1996, downloadable at http://www.federalreserve.gov/boarddocs/speeches/1996/19961205.htm.

[7]www.ecb.int/key/00/sp000608.htm

[8]http://www.bankofengland.co.uk/speeches/speech181.pdf

[9]The literature on global games (Carlsson and van Damme (1993)) provided a theoretical foundation for overweighing public information relative to its purely informational content (Morris and Shin (2000)). Nevertheless, this paper does not use a global game as a basis for analysing a policymaker's publication strategy. The reason is that global games are coordination games, and although many macroeconomic phenomena can be interpreted as outcomes of coordination games (cf. Cooper (1998)), it appears difficult to justify why social welfare should not be monotone in players' equilibrium action. Generally, these models emphasise the possibility of coordination failure, the absence of which is socially preferred. As explained above, monotonicity leads to full revelation.

3.2 Distributional assumptions

Suppose the policymaker attaches no importance to his signal: He assumes that the signal is uncorrelated with the demand intercept. In contrast, all firms believe that the signal is perfectly correlated. Consequently, their conditional estimate of the demand intercept when the policymaker reports $s = \{t\}$ is $E[A|s = \{t\}] = t$. This difference in interpretation is common knowledge among players.

The following section briefly summarises the results, which are derived subsequently.

3.3 Results

Suppose that the policymaker's reporting rule prescribes to send $s = \{t\}$ for all types $t \in T_s \subset \Omega$ and to withhold his private information (to send $s = \Omega$) for all other types $t' \in T_w = \Omega \backslash T_s$. (Recall that in this paper, only pure strategies are considered.) It is assumed that out of all equilibrium reporting rules, the policymaker chooses the one that, conditional on his type, maximises his expectation of social welfare. (I.e., players coordinate on this equilibrium.)

The uniform distribution assumption implies that in equilibrium, there are at most six types indifferent between publishing and withholding. Thus, Ω is partitioned in at most seven intervals, where all types in one interval either publish or withhold, and types in adjacent intervals do not both withhold or both publish. The set of equilibria can be reduced by showing that types in the highest and the lowest interval always withhold their information in equilibrium (proposition 1). Thus, the following families of reporting rules remain candidates for a partially revealing equilibrium: (w-p-w-p-w-p-w), (w-p-w-p-w), and (w-p-w), where e.g. '(w-p-w)' indicates that low types withhold, intermediate types publish, and high types withhold.

The search for the equilibrium that maximises social welfare can be simplified by noting that in each partially revealing equilibrium, there is at least one type t^* at which firms' estimate of the demand intercept when the information is withheld is equal to t^* (proposition 2). Firms' expectations about the demand intercept when the policy-maker withholds determine, in turn, production and thereby welfare when the signal

is withheld. Thus, choosing T_w which maximises welfare is equivalent to choosing the equilibrium reporting rule with the highest t^*.

Among rules of the type (w-p-w), if costs of building capacity are sufficiently high, the welfare maximising (sequential) equilibrium rule is unique (if it exists) and has the following properties (proposition 3): The higher the policymaker's incentive is to increase production (cf. definition 2),

- the wider the range of news he publishes: The worse the worst news, and the better the best news he is forced to make public;

- the lower firms' expectation of the news in the withholding interval;

- the better the average news in the publishing interval.

This equilibrium also exists for low costs of building capacity, but no uniqueness result has been obtained so far. Rules of the types (w-p-w-p-w-p-w) and (w-p-w-p-w) have not yet been analysed.

The following section contains the propositions their derivations, and a numerical example. Subsections 3.4.1 and 3.4.2 derive expression for the policymaker's expectation of welfare after publishing and withholding his information. Subsection 3.4.3 presents an initial characterisation of the equilibrium reporting rules (if they exist.) Subsection 3.4.4 adds some more properties for rules of the form (w-p-w). Subsection 3.4.5 shows existence of (w-p-w) rules for some parameter values by deriving them explicitly before subsection 3.4.6 presents comparative static results. Subsection 3.5 presents a numerical example and uses numerical solutions to suggest that (w-p-w) - type rules exist for a wider range of parameters than analysed in 3.4.5 .

3.4   Derivations

3.4.1   The policymaker's expectation of welfare

Assuming that A is uniformly distributed in Ω, we have

$$E\left[W\left(A\right)\right] \;=\; \int_{\alpha}^{\beta}\left(-cQ + \left\{ \begin{array}{cl} \frac{1}{2}Q\left(2a - Q\right) & \text{if} \quad Q < a \\ \frac{1}{2}a^2 & \text{if} \quad Q > a \end{array} \right\}\right) \frac{1}{\beta - \alpha} da \qquad (5)$$

11

$$= -cQ + \frac{1}{\beta - \alpha} \int_\alpha^\beta \left(\left\{ \begin{array}{ll} \frac{1}{2}Q(2a - Q) & \text{if } Q < a \\ \frac{1}{2}a^2 & \text{if } Q > a \end{array} \right\} \right) da$$

Thus, considering the different intervals separately, on gets (recall that the policymaker knows Q given his decision to make his private information public or withhold it, but he does not know demand: so his expectation is running over demand):

1. If $Q \leq \alpha$, demand is always sufficiently low to avoid unused capacity. That is, $a \geq Q$ for all a and thus

$$\int_\alpha^\beta (.) \, da = \int_\alpha^\beta \left(\frac{1}{2}Q(2a - Q) \right) da = \frac{1}{2}Q(\beta - \alpha)(\beta + \alpha - Q) \quad (6)$$

   Recall that because production costs are zero, firms always reduce prices in response to low demand down to a level of zero. Costs cQ of building capacity are sunk.

2. If $\alpha < Q < \beta$, low realisations of demand may cause capacity to remain idle. Thus,

$$\int_\alpha^\beta (.) \, da = \int_\alpha^Q \left(\frac{1}{2}a^2 \right) da + \int_Q^\beta \left(\frac{1}{2}Q(2a - Q) \right) da \quad (7)$$
$$= \frac{1}{6}(Q^3 - \alpha^3) + \frac{1}{2}Q\beta(\beta - Q)$$

3. Finally, if $\beta < Q$, production exceeds even the highest possible level of demand at zero prices.

$$\int_\alpha^\beta (.) \, da = \int_\alpha^\beta \left(\frac{1}{2}a^2 \right) da = \frac{1}{6}(\beta^3 - \alpha^3) \quad (8)$$

Taking the results together, we have

$$E[W(A)] = -cQ + \frac{1}{\beta - \alpha} \left\{ \begin{array}{ll} \frac{1}{2}Q(\beta - \alpha)(\beta + \alpha - Q) & \text{if} \quad Q < \alpha \\ \frac{1}{6}(Q^3 - \alpha^3) + \frac{1}{2}Q\beta(\beta - Q) & \text{if} \quad \alpha \leq Q \leq \beta \\ \frac{1}{6}(\beta^3 - \alpha^3) & \text{if} \quad Q > \beta \end{array} \right. \quad (9)$$
$$= -cQ + \frac{1}{2} \left\{ \begin{array}{ll} Q(\beta + \alpha - Q) & \text{if} \quad Q < \alpha \\ \frac{1}{3(\beta - \alpha)}(Q^3 - \alpha^3) + \frac{1}{(\beta - \alpha)}Q\beta(\beta - Q) & \text{if} \quad \alpha \leq Q \leq \beta \\ \frac{1}{3}(\alpha^2 + \beta\alpha + \beta^2) & \text{if} \quad Q > \beta \end{array} \right.$$

Under the distributional assumptions made above, firms always fully trust the signal if it is published, and the signal support is identical to the support Ω of the demand intercept. Thus, whether or not the policymaker sends $s = \{t\}$, firms' expectation of the demand intercept never exceeds β. Thus, a firm's optimal production never exceeds $\frac{1}{F+1}(\beta - c)$ and the policymaker never expects aggregate production to lie strictly above β. Consequently, the expression for aggregate welfare can be simplified further to

$$E[W(A)] = -cQ + \frac{1}{2} \begin{cases} Q(\beta + \alpha - Q) & \text{if } Q < \alpha \\ \frac{1}{3(\beta-\alpha)}(Q^3 - \alpha^3) + \frac{1}{(\beta-\alpha)}Q\beta(\beta - Q) & \text{if } \alpha \leq Q \end{cases} \tag{10}$$

where $Q \leq \beta$.

To derive the policymaker's target level of capacity, suppose for the moment that he could choose Q without constraint. Then expected welfare is maximised if marginal costs of providing an additional unit of capacity equals marginal benefits:

$$c = \frac{1}{2} \begin{cases} \beta + \alpha - 2Q & \text{if } Q < \alpha \\ \frac{1}{\beta-\alpha}Q^2 + \frac{1}{(\beta-\alpha)}\beta(\beta - 2Q) & \text{if } \alpha \leq Q \end{cases}$$

Thus, the policymaker's target quantity of output is[10]

$$\hat{Q} = \begin{cases} \frac{1}{2}(\beta + \alpha) - c & \text{if } c > \frac{1}{2}(\beta - \alpha) \\ \beta - \sqrt{2c(\beta - \alpha)} & \text{if } c < \frac{1}{2}(\beta - \alpha) \end{cases} \tag{11}$$

This expression simply says that desired production is always increasing in the upper and lower bound of the support of the demand intercept, and decreasing in the cost. For low costs, optimal production is increasing less than linearly (but still $\frac{\partial\left(\beta - \sqrt{2c(\beta-\alpha)}\right)}{\partial\beta} > 0$ for $2(\beta - \alpha) > c$). The reason is that for low costs, the incentive to increase capacity must be balanced with the danger of providing overcapacity, should demand turn out to be unexpectedly low. This problem does not arise in the first case where costs are sufficiently high to ensure that the socially desirable capacity level is always below any possible realisation of demand: $\frac{1}{2}(\beta + \alpha) - c < \frac{1}{2}(\beta + \alpha) - \frac{1}{2}(\beta - \alpha) = \alpha$.

---

[10]When solving the above for Q, the larger root in Q is strictly larger than b and thus no solution to the problem.

3.4.2 Aggregate production and expected welfare as a function of the publication decision.

PM publishes. In this case, firms' posterior expectation of the demand intercept A is equal to the policymaker's type t. Then

$$Q^p (s = \{t\}) = \frac{F}{F+1} (t - c) \tag{12}$$

and, entering (12) into (10), one obtains the policymaker's expectation of total welfare:

$$E[W(A)|s = \{t\}] = -cQ^p \tag{13}$$
$$+\frac{1}{2} \left\{ \begin{array}{ll} Q^p (\beta + \alpha - Q^p) & \text{if } s \leq c + \frac{F+1}{F}\alpha \\ \frac{1}{3(\beta-\alpha)} \left((Q^p)^3 - \alpha^3\right) + \frac{1}{(\beta-\alpha)}Q^p\beta(\beta - Q^p) & \text{if } s > c + \frac{F+1}{F}\alpha \end{array} \right.$$

Thus, if $s \leq c + \frac{F+1}{F}\alpha$, then total capacity provided will with certainty fall behind demand when prices are zero. This does, however, not mean that a capacity close to the lower bound α of the support of the demand intercept is socially desirable: This depends on costs, and the policymaker desires $\hat{Q} = \frac{\alpha+\beta}{2} - c$. From the policymaker's perspective, the higher costs c, the greater the danger of overprovision of capacity if he publishes the signal - even if $s \leq c + \frac{F+1}{F}\alpha$.

PM withholds signal Suppose that the policymaker's reporting rule prescribes to send $s = \{t\}$ for all types $t \in T_s \subset \Omega$ and to withhold his private information (to send $s = \Omega$) for all other types $t' \in T_w = \Omega \backslash T_s$. (Recall that in this paper, only pure strategies are considered.) In a partially revealing equilibrium, T_w contains more than one element.

The conditional distribution $f_A(a|s = \Omega)$ of the demand intercept after withholding is

$$f_A(a|s = \Omega) = \left\{ \begin{array}{ll} \frac{1}{m} & \text{if } \alpha \in T_w \\ 0 & \text{if } \alpha \in T_s \end{array} \right. \tag{14}$$

where $m \equiv \int_{t \in T_w} dt$. Firms' posterior expectation of the demand intercept α is

$$E[A|s = \Omega] = \frac{1}{m} \int_{t \in T_w} t \, dt \tag{15}$$

14

which is quadratic in the types which are just indifferent between publishing and withholding. The quantity produced after the policymaker withheld is

$$Q^{wh} = \frac{F}{F+1} \left(E\left[A|s=\Omega\right] - c\right) \tag{16}$$

$$= \frac{F}{F+1} \left(\frac{\int_{t\in T_w} t\, dt}{\int_{t\in T_w} dt} - c\right)$$

and the policymaker's expectation of welfare is

$$E\left[W\left(A\right)|s=\Omega\right] = -cQ^{wh} \tag{17}$$

$$+\frac{1}{2}\left\{ \begin{array}{ll} Q^{wh}\left(\beta + \alpha - Q^{wh}\right) & \text{if} \quad E\left[A|s=\Omega\right] \le c + \frac{F+1}{F}\alpha \\ \frac{1}{3(\beta-\alpha)}\left(\left(Q^{wh}\right)^3 - \alpha^3\right) + \frac{1}{(\beta-\alpha)}Q^{wh}\beta\left(\beta - Q^{wh}\right) & \text{if} \quad E\left[A|s=\Omega\right] > c + \frac{F+1}{F}\alpha \end{array}\right.$$

Combining these expressions (17) and (13), the policymaker's expected welfare can be written as

$$E\left[W\left(A\right)|t\right] = \left\{ \begin{array}{ll} E\left[W\left(A\right)|s=\Omega\right] & \text{if} \quad t \in T_w \\ E\left[W\left(A\right)|s=\{t\}\right] & \text{if} \quad t \in T_s \end{array}\right. \tag{18}$$

The following sections first derive the form of reporting rules which lead to a partially revealing equilibrium. The second step would be to select the reporting rule which, over all credible reporting rules, maximises social welfare. (By assumption, players coordinate on this rule.) However, so far, only results for the welfare-maximising reporting rule within the class of credible rules of the type (w-p-w): "withhold bad and good information and publish intermediate information", have been obtained. Comparative statics for this rule follow.

3.4.3 Description of the family of equilibrium reporting rules

By definition, policymaker types who are at the points at which I_w and I_s connect must be indifferent between publishing and withholding. All policymaker types whose type t satisfies $E\left[W\left(A\right)|s=\{t\}\right] = E\left[W\left(A\right)|s=\Omega\right]$ are indifferent between publishing and withholding. Comparing with (13), (16) and (17), one sees that this equation is a sixth-order polynomial in t; thus, it can have at most six real roots, or at most seven adjacent intervals in which the policymaker alternately publishes and withholds. Fortunately, the set of equilibria can be reduced:

15

Proposition 1 *The highest and the lowest interval in any equilibrium that is not fully revealing must be a withholding interval.*

Proof. Recall that Q^p is strictly increasing in the (published) signal (eq. (12)), that all types share a common capacity target $\hat{Q}$ (eq. (11)), and that the policymaker's target function is strictly concave in Q (eq. (10)). Suppose in contrast to the proposition that the highest interval is a publishing interval and the second highest a withholding interval, and call t' the type which is the supremum of the second-highest interval.

If t' withholds, $Q^{wh} < \hat{Q}$: Firms' conditional expectation of the demand intercept A when the policymaker withholds his information is strictly smaller than t'. Thus, $Q^p(s = \{t'\}) > Q^{wh}$. Because even the highest type β prefers to publish, the capacity built when the signal is withheld must be below the policymaker's target.

t' strictly prefers to publish: Suppose now that sending $s = \{t'\}$ leads to production above target. Then type t' strictly prefers to publish because type $\beta > t'$ strictly prefers to publish, and the publication of β's type causes capacity to be even larger. Suppose instead that sending $s = \{t'\}$ yields a capacity below the target. But because all types above t' publish, firms' conditional expectation of A when t' withholds his information is strictly below t'. Thus, withholding causes the target to be missed by more than publishing. Consequently, t' strictly prefers to publish, in contrast to the assumption that he is indifferent.

Thus, in all partially revealing equilibria, the highest interval must be a withholding interval.

A corresponding argument holds for the lowest interval: Call t'' the supremum of the lowest interval. Because the lowest type α prefers to publish, the capacity that is built when the signal is withheld must exceed the target. If sending $s = \{t''\}$ causes capacity to lie below target, t'' strictly prefers to publish because even type $\alpha < t''$ preferred to publish, and Q^p is strictly increasing in the published signal. If instead sending $s = \{t''\}$ causes production to lie above target, t'' strictly prefers to publish because withholding would cause the target to be missed by even more. ∎

Thus, the following families of reporting rules remain candidates for a partially revealing equilibrium: (w-p-w-p-w-p-w), (w-p-w-p-w), and (w-p-w), where e.g. '(w-p-w)'

indicates that low types withhold, intermediate types publish, and high types withhold.

The following lemmata simplify the search for the equilibrium reporting rule that maximises expected welfare. (Recall that I assume that players coordinate on this rule.)

Lemma 1 $E\left[W\left(A\right)|t\right]$ *reaches its maximum when* $E\left[W\left(A\right)|s=\Omega\right]$ *is maximal.*

Proof. Capacity after $s=\{t\}$ only depends on t, but not on T_s (cf. eq. (12)). Thus, expected welfare when the signal is published is independent of T_w. In contrast, production after $s=\Omega$ depends on T_w (cf. eq. (16)). Thus, $E\left[W\left(A\right)|t\right]$ only depends on the choice of I_w through $E\left[W\left(A\right)|s=\Omega\right]$. ∎

Corollary 1 *Conditional on* t*, expected welfare under a partially revealing rule is in equilibrium always at least as high as expected welfare under full revelation.*

Lemma 2 *If there is a partially revealing equilibrium, then there is a* $t^* \in \Omega$ *such that* $Q^p\left(s=\{t\}^*\right)=Q^{wh}$*, that is,* t^* *fulfills*

$$t^* = \frac{\int_{t\in T_w} t\,dt}{\int_{t\in T_w} dt} \tag{19}$$

Proof. Type t^* is indifferent between publishing and withholding because both actions would lead to the same aggregate output. Suppose t^* does not exists. Then either $Q^p\left(s=\{t\}\right) > Q^{wh}$ for all $t \in \Omega$, or $Q^p\left(s=\{t\}\right) < Q^{wh}$ for all $t \in \Omega$, because $Q^p\left(s=\{t\}\right)$ and Q^{wh} are continuous. Assume that $Q^p\left(s=\{t\}\right) > Q^{wh}$ for all $t \in \Omega$. Recall that the policymaker's target output $\hat{Q}$ fulfills $Q^p\left(s=\alpha\right) < \hat{Q} < Q^p\left(s=\{\beta\}\right)$, that expected welfare is strictly concave in Q, and that Q^p is strictly increasing in t. Then type $t=\alpha$ strictly prefers to publish. Assume instead that $Q^p\left(s=\{t\}\right) < Q^{wh}$ for all $t \in \Omega$. Then type $t=\beta$ strictly prefers to publish. From proposition 1, in all partially revealing equilibria, the lowest and the highest types need to withhold. Thus, if t^* does not exist, then no partially revealing equilbrium exists. ∎

Lemma 3 *Suppose a partially revealing equilibrium exists. Then choosing* I_w *among partially revealing equilibria to maximise* $E\left[W\left(A\right)|t\right]$ *is equivalent to choosing* t^* *to maximise* $E\left[W\left(A\right)|t\right]$*, where* t^* *is given by (19).*

17

Proof. Q^p is a strictly incresing function of s. By lemma 2, t^* exists in every partially revealing equilibrium. By definition, $Q^p\left(s = \{t^*\}\right) = Q^{wh}$. Thus, Q^{wh} is strictly increasing in t^*. Consequently, for each Q^{wh} that maximises expected welfare when the signal is withheld, there is a unique t^* that maximises expected welfare when the signal is withheld. Finally, by lemma 1, welfare is maximal if welfare when the signal is withheld is maximal. ∎

The following section focuses on equilibria in which the policymaker's reporting rule is of the type (w-p-w).

3.4.4   Some properties of reporting rules of the form w-p-w (only types $t \in [x, y]$ publish, where $\alpha < x < y < \beta$.)

In this case, firms' posterior expectation of the demand intercept A is (from eq. (15))

$$
\begin{aligned}
E\left[A|s = \Omega\right] &= \frac{1}{(\beta - y) + (x - \alpha)}\left(\int_\alpha^x a\,da + \int_y^\beta a\,da\right) \\
&= \frac{1}{2}\frac{\beta^2 - y^2 - \alpha^2 + x^2}{\beta - y + x - \alpha}
\end{aligned}
$$

Thus, aggregate production is (from eq. (16))

$$
\begin{aligned}
Q^{wh} &= \frac{F}{F+1}\left(E\left[A|s = \Omega\right] - c\right) \\
&= \frac{F}{F+1}\left(\frac{1}{2}\frac{\beta^2 - y^2 + x^2 - \alpha^2}{\beta - y + x - \alpha} - c\right)
\end{aligned}
$$

This expression can be simplified by noticing that $E\left[A|s = \Omega\right] = x$. Lemma 4 established a preliminary result:

Lemma 4 *If the partially revealing equilibrium takes the form that only types $t \in [x, y]$ publish, where $\alpha < x < y < \beta$, then the lower bound of the publication interval is smaller than the prior expectation of the demand intercept.*

Proof.   By contradiction. Assume that all signals below x are withheld, but that $x \geq E\left[A\right]$. Then the posterior expectation after a signal has been withheld lies strictly below $E\left[A\right]$ under the uniform prior assumption. It can be readily verified that $E\left[A|s = \Omega\right]$ is strictly increasing in x for $x \geq \frac{\alpha+\beta}{2}$, and at $x = \frac{\alpha+\beta}{2}$, $E\left[A|s = \Omega\right] < E\left[A\right] = \frac{\alpha+\beta}{2}$

if $y > E[A]$. But then there is a non-empty interval of types with supremum $E[A]$ in which each type would have a strict preference for publishing his signal because he could thereby lift firms' expectation of the demand intercept, moving capacity towards the level he prefers. Put differently, we cannot have that the policymaker only publishes better-than-average information. ∎

Proposition 2 *If the partially revealing equilibrium takes the form that only types $t \in [x, y]$ publish, where $\alpha < x < y < \beta$, then type x expects total production to be unaffected by his publication decision, and type y expects that publication leads to production above target, whereas it undershoots his target when he withholds.*

Proof. Suppose that such x, y exist. From lemma 2, in a partially revealing equilibrium, there is a type t^* whose publication decision leaves aggregate capacity unchanged. Firms' conditional expectation of the demand intercept after observing $s = \{t\}$ is strictly increasing in the signal, and a constant function of the policymaker's type if $s = \Omega$. Thus, if types smaller than t^* publish, firms' posterior estimate is smaller than after $s = \Omega$; if types larger than t^* publish, firms' posterior estimate is larger compared to their estimate if $s = \Omega$.

From lemma 4, x is strictly smaller than the prior mean. Thus, all types smaller than x have a strict preference to withhold, and all types larger than x have a strict preference to publish. This implies $x = t^*$.

Finally, we need to characterise y. $y > x$ implies that $Q^p(t = y) > Q^p(t = x)$. Because all types share the same target level of production $\hat{Q}$, a sufficiently high type y will be just indifferent between publishing and withholding. If he withholds, he undershoots his target level. If he publishes, he overshoots. ∎

The following section analyses conditions under which such x, y exist.

3.4.5 Existence and derivation of a reporting rule of the form (w-p-w)

Existence is shown by solving the equation

$$E[A|s = x] = \frac{1}{2} \frac{\beta^2 - \alpha^2 - (y^2 - x^2)}{\beta - \alpha - (y - x)} = x \tag{20}$$

This is quadratic in x, and thus, we can have at most two different reporting rules of the form (w,p,w). Solving for y yields $y_{1,2} = x \pm \sqrt{\beta^2 - \alpha^2 - 2x(\beta - \alpha)}$ only the larger root of which fulfils the condition $x \leq y$. This root is real if $x \leq \frac{1}{2}(\beta + \alpha) = E[A]$, a reflection of the fact that lemma 4 was used to derive equation (20). Notice also that $y < \beta$ if $\beta^2 - \alpha^2 - 2x(\beta - \alpha) < (\beta - x)^2$ iff $-(x - \alpha)^2 < 0$ which is always true. Thus, the limits x, y of the publication interval need to fulfill:

$$
\begin{aligned}
\alpha &< x \leq \frac{1}{2}(\beta + \alpha) \\
y &= x + \sqrt{\beta^2 - \alpha^2 - 2x(\beta - \alpha)}
\end{aligned}
$$

The following lemmata describe some properties of the publication window:

Lemma 5 *The upper bound of the publication interval is strictly decreasing in the lower bound.*

Proof. $\frac{\partial}{\partial x}\left(x + \sqrt{\beta^2 - \alpha^2 - 2x(\beta - \alpha)}\right) = \frac{\sqrt{((-\beta+\alpha)(-\alpha+2x-\beta))} - \beta + \alpha}{\sqrt{((-\beta+\alpha)(-\alpha+2x-\beta))}} < 0$ if $\alpha < x$. ∎

Corollary 2 *As the lower bound of the publication interval rises, the publication window $y - x$ shrinks.*

Thus, the larger the lower bound, the smaller the interval in which the policymaker prefers to publish information. A larger x means that more bad information is withheld. Correspondingly, the policymaker withholds more good information to raise the firm's expected value of the signal when he withholds the information. Thus, the publication window shrinks.

Lemma 6 *The midpoint of the publication interval rises as its lower bound x falls if $x > \frac{3}{8}\beta + \frac{5}{8}\alpha$*

Proof.

$$
\begin{aligned}
\frac{\partial}{\partial x}\left(\frac{y+x}{2}\right) &= \frac{1}{2}\frac{\partial}{\partial x}\left(x + \sqrt{\beta^2 - \alpha^2 - 2x(\beta - \alpha)} + x\right) & (21) \\
&= \frac{1}{2}\frac{\partial}{\partial x}\left(2x + \sqrt{\beta^2 - \alpha^2 - 2x(\beta - \alpha)}\right) \\
&< 0 \text{ if } x > \frac{3}{8}\beta + \frac{5}{8}\alpha
\end{aligned}
$$

■

To show existence, we now need to solve explicitly for x, y. Recall that we need to equate $E\left[W\left(A\right)|s=\{t\}\right]=E\left[W\left(A\right)|s=\Omega\right]$ to find types x, y which are just indifferent between publishing and withholding. Proposition 2 established that $Q^{wh}=Q^p\left(s=x\right)=\frac{F}{F+1}\left(x-c\right)$. Thus, we need to solve for x in $E\left[W\left(A\right)|s=\Omega\right]=E\left[W\left(A\right)|s=y\left(x\right)\right]$ where

$$E\left[W\left(A\right)|s=\Omega\right] = -cQ^{wh}$$
$$+\frac{1}{2}\begin{cases} Q^{wh}\left(\beta+\alpha-Q^{wh}\right) & \text{if } x\leq c+\frac{F+1}{F}\alpha \\ \frac{1}{3(\beta-\alpha)}\left(\left(Q^{wh}\right)^3-\alpha^3\right)+\frac{1}{(\beta-\alpha)}Q^{wh}\beta\left(\beta-Q^{wh}\right) & \text{if } x>c+\frac{F+1}{F}\alpha \end{cases}$$

$$E\left[W^p\left(\alpha\right)|S=y\right] = -cQ^p+\frac{1}{2}\begin{cases} Q^p\left(\beta+\alpha-Q^p\right) & \text{if } y\leq c+\frac{F+1}{F}\alpha \\ \frac{1}{3(\beta-\alpha)}\left(\left(Q^p\right)^3-\alpha^3\right)+\frac{1}{(\beta-\alpha)}Q^p\beta\left(\beta-Q^p\right) & \text{if } y>c+\frac{F+1}{F}\alpha \end{cases}$$

$$Q^{wh} = \frac{F}{F+1}\left(x-c\right)$$
$$Q^p = \frac{F}{F+1}\left(y-c\right)$$

and

$$\alpha < x\leq\frac{1}{2}\left(\beta+\alpha\right)$$
$$y = x+\sqrt{\beta^2-\alpha^2-2x\left(\beta-\alpha\right)}$$

The following section only solves explicitly for the case that costs are high, causing the total quantity produced to fall short of the demand intercept, whether the policymaker publishes or withholds. (Numerical solutions for smaller costs are provided in section 3.5.) That is, suppose that for all solutions y that solve this problem, we have

$$y\leq c+\frac{F+1}{F}\alpha \tag{22}$$

If $y\leq c+\frac{F+1}{F}\alpha$, we also have $x\leq c+\frac{F+1}{F}\alpha$, and welfare is quadratic in Q both when the policymaker withholds and when he publishes, and thus of fourth order in t. The production target $\hat{Q}=E\left[A\right]-c=\frac{\alpha+\beta}{2}-c$, independent of t. From proposition 2, expected production overshoots the target at $S=y$. Also, for the region in which welfare

21

is quadratic, undershooting the target by ΔQ hurts welfare by as much as overshooting it by ΔQ. Thus, we can derive the (x, y) directly from $\hat{Q} - Q^{wh} = Q^p - \hat{Q}$ or

$$Q^p = 2\hat{Q} - Q^{wh}$$

Entering the expressions for the expected quantities yields

$$\frac{F}{F+1}\left(x - c + \sqrt{\beta^2 - \alpha^2 - 2x(\beta - \alpha)}\right) = 2\left(\frac{\alpha + \beta}{2} - c\right) - \frac{F}{F+1}(x - c)$$

which has the solutions

$$x_{1,2} = \frac{\beta + 3\alpha}{4} + \frac{1}{F}\left(\frac{1}{2}(\beta + \alpha) - c \pm \frac{1}{4}\sqrt{F(\beta - \alpha)(F(\beta - \alpha) - 4((\beta + \alpha) - 2c))}\right) \tag{23}$$

Thus, there is no (real) solution to the problem if

$$F(\beta - \alpha)(F(\beta - \alpha) - 4((\beta + \alpha) - 2c)) < 0$$

equivalently $c + \frac{1}{8}F(\beta - \alpha) < \frac{1}{2}(\beta + \alpha)$, that is, when costs are too small, or the industry is relatively incompetitive (F low). In this case, the policymaker's incentive to raise production (cf. definition 2) is so high that in no reporting rule of the form (w-p-w), there is a type t^* for which firms' expectation of the type after he withheld his information are equal to their expectation of his type after he publishes. Thus, a partially revealing reporting rule cannot exist in this class of reporting rules.

There is exactly one real solution if $c + \frac{1}{8}F(\beta - \alpha) = \frac{1}{2}(\beta + \alpha)$, equivalently, if

$$F = 4\frac{\beta + \alpha - 2c}{\beta - \alpha} \tag{24}$$

In this case,

$$\begin{aligned} x &= x_m \equiv \frac{1}{4F}\left((\beta + 3\alpha)F + 2(\beta + \alpha) - 4c\right) \\ &= \frac{3}{8}\beta + \frac{5}{8}\alpha \end{aligned}$$

where the last line follows from entering the uniqueness condition for F. The upper bound of the publication interval is then

$$\begin{aligned} y &= y_m \equiv x_m + \sqrt{\beta^2 - \alpha^2 - 2x_m(\beta - \alpha)} \\ &= \frac{7}{8}\beta + \frac{1}{8}\alpha \end{aligned}$$

22

Consequently, if $F = 4\frac{\beta+\alpha-2c}{\beta-\alpha}$, the unique credible reporting rule of the form (w-p-w) is

$$s(t) = \begin{cases} t & \text{if} \quad t \in \left[\frac{5}{8}\alpha + \frac{3}{8}\beta, \frac{1}{8}\alpha + \frac{7}{8}\beta\right] \\ \Omega & \text{else} \end{cases}$$

There are two real solutions to equation (23) if $c + \frac{1}{8}F(\beta - \alpha) > \frac{1}{2}(\beta + \alpha)$. By lemma 3, choosing a withholding interval T_w to maximise welfare is equivalent to choosing x to maximise welfare. By lemma 4, publishing x results in a capacity smaller than the policymaker's target. Also, welfare is concave and, therefore, rising when the deviation between actual capacity and its target shrinks. Thus, only the higher root of equation (23) maximises welfare within the class of rules with the form (w-p-w). Thus, if $F > 4\frac{\beta+\alpha-2c}{\beta-\alpha}$ and $y_h = x_h + \sqrt{\beta^2 - \alpha^2 - 2x_h(\beta - \alpha)} \le c + \frac{F+1}{F}\alpha$, the unique expected-profit-maximising reporting rule out of the family of reporting rules which take the form (w-p-w) is

$$s(t) = \begin{cases} \{t\} & \text{if} \quad t \in \left[x_h, x_h + \sqrt{\beta^2 - \alpha^2 - 2x_h(\beta - \alpha)}\right] \\ \Omega & \text{else} \end{cases} \tag{25}$$

where x_h is given by

$$x_h = \frac{\beta + 3\alpha}{4} + \frac{1}{F}\left(\frac{1}{2}(\beta + \alpha) - c + \frac{1}{4}\sqrt{F(\beta - \alpha)(F(\beta - \alpha) - 4((\beta + \alpha) - 2c))}\right) \tag{26}$$

Notice that the assumption that the policymaker attaches no importance to the information he receives, whereas firms put full weight on it, makes expected welfare when $s = \{t\}$ is sent sufficiently convex to ensure that a partially revealing equilibrium exists: For the interval under consideration, it is commonly known that under no circumstances, capacity will remain unused (Q is smaller than the lower bound of the support of the demand intercept α.). Thus, there appears to be room to weaken this very strict form of heterogeneous interpretation of the information, and still be able to obtain a credible publication strategy which prescribes to withhold information for some realisations.

3.4.6 Comparative statics

The following proposition summarises comparative static results for the rule in eq. (25).

Proposition 3 *The higher the policymaker's incentive is to increase production,*

1. *the worse the worst news he makes public;*

2. *the better the best news he makes public;*

3. *the lower agents' expectation of the news he withholds;*

4. *the better the average news he publishes.*

Proof. Recall that the policymaker's incentive to increase production is decreasing in both marginal costs c and number of firms F (cf. definition 2). Then

1. follows directly from

$$\frac{\partial x_h}{\partial F} = \frac{(\beta + \alpha - 2c)\left(F(\beta - \alpha) - \sqrt{(F(\beta - \alpha))^2 - F(\beta - \alpha)4((\beta + \alpha) - 2c)}\right)}{F^2\sqrt{(F(\beta - \alpha))^2 - 4F(\beta - \alpha)((\beta + \alpha) - 2c)}} > 0$$

and

$$\frac{\partial x_h}{\partial c} = \frac{\left((\beta - \alpha)F - \sqrt{(F(\beta - \alpha))^2 - 4F(\beta - \alpha)((\beta + \alpha) - 2c)}\right)}{F\sqrt{(F(\beta - \alpha))^2 - 4F(\beta - \alpha)((\beta + \alpha) - 2c)}} > 0$$

2. follows from 1. and the fact that y is strictly decreasing in x (lemma 5);

3. follows from 1. and $E[A|s = \Omega] = x$ (propostion 2);

4. follows from 1. combined with $x_h > \frac{5}{8}\alpha + \frac{3}{8}\beta$ and the fact that the midpoint of the publication window rises in x for $x > \frac{5}{8}\alpha + \frac{3}{8}\beta$ (lemma 2).

∎

Notice that if the economy becomes perfectly competitive, both x_h and y_h converge towards $\frac{1}{2}(\beta + \alpha)$, the policymaker's posterior (=prior) mean. In this case, the policymaker can "afford" to withhold all information that he thinks causes the market to overreact.

The following section illustrates the equilibrium reporting rule found in equation (25) with a numerical example, and "extends" it to cases in which $y > c + \frac{F+1}{F}\alpha$ via numerical solution methods.

3.5   An example

Suppose the demand intercept is distributed uniformly in $\Omega = [1, 2]$, that the industry is relatively uncompetitive ($F = 10$) and that costs $c = 1 \le \alpha$ need to be spent to build up one unit of capacity. In this case, $x_h = 1.49$, $y_h = 1.60 \le c + \frac{F+1}{F}\alpha = 2.1$ and we are in the case for which (25) gives the unique welfare-maximising credible reporting rule.

Chart (a) shows the production target (dotted), production when the policymaker withholds information (horizontal line), and production when the signal is published (upwards sloping line) depending on the policymaker's type.
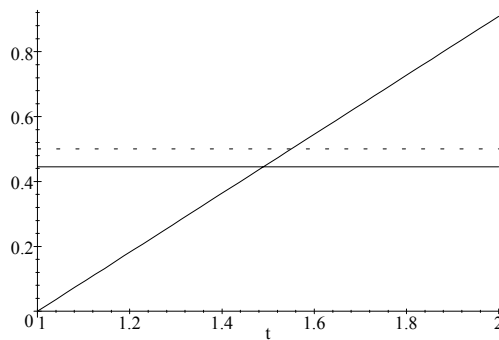

(a)

Clearly, publishing the information causes aggregate production to undershoot the policymaker's target when the information is bad, and to overshoot his target when it is good. Thus, for these extreme news, the policymaker prefers to withhold his information. (Again: The fact that the policymaker's target is independent of his type is an extreme assumption that simplifies the calculation. A similar result could probably be obtained when assuming that target is increasing in the policymaker's type, but less than production when he publishes.) Chart (b) uses expected welfare when the signal is published, when it is withheld, and the largest attainable welfare (from which target production is derived), to convey the same information:
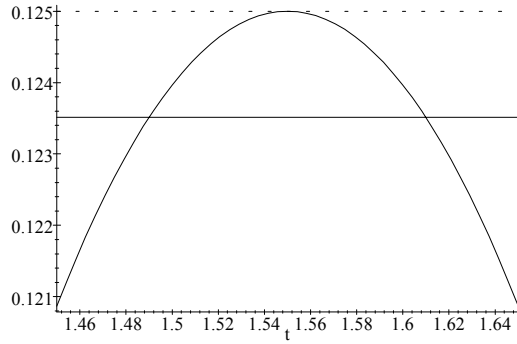
(b)

The intersections of the concave line (expected welfare after publishing) and the lower horizontal line (expected welfare after withholding) define the indifference points (x, y) which enclose the publication interval.

Chart (c) shows how the publication interval changes when the economy becomes less competitive, increasing the policymaker's incentive to stimulate output. Given the parameter values above, full revelation is the only equilibrium that exists in very incompetitive economies ($F \in \{1, 2, 3\}$). The uniqueness condition (24) is fulfilled for $F = 4$. In this case, the family of rules of the type (w-p-w) contains only one rule in which the policymaker publishes if and only if his type is in $\left[\frac{11}{8}, \frac{15}{8}\right]$. (Notice that equation (26) can be used to compute all the solutions because $y_h (F = 4) = \frac{15}{8} \leq \lim_{F \to \infty} \left(c + \frac{F+1}{F}\alpha\right) = c + \alpha = 2$.)
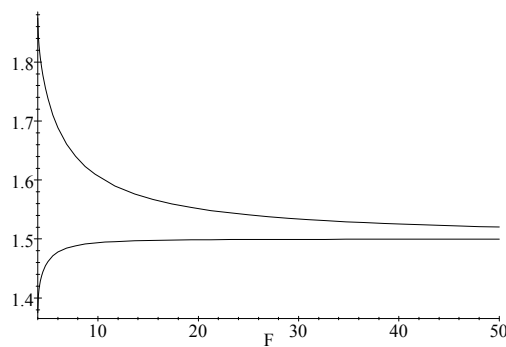
(c)

Clearly, the more competitive the economy (the higher F), the smaller the policymaker's incentive to stimulate the economy, and the more he can afford to hide extreme news which, according to his view, would cause the market to overreact if published.

26

The final chart (d) presents again the boundaries, but this time for the case in which condition (22): $y \leq c + \frac{F+1}{F}\alpha$, only holds for large F. (This was chosen to have an easy check for the numerical solution at $y = c + \frac{F+1}{F}\alpha$.) That is, suppose that marginal costs of building capacity are lower at $c = 0.54$. Then $\lim_{F\to\infty}(y) = \frac{\alpha+\beta}{2} = \frac{3}{2} \leq \lim_{F\to\infty}\left(c + \frac{F+1}{F}\alpha\right) = 1.54$. In contrast, for $F < 25$, condition (22) is violated and thus, for the moment, recourse has been made to numerical solutions. The chart presents condition (22) (dotted) in addition to the two bounds of the publication interval. For $F > 25$, (22) is fulfilled and (26) can be used to compute the bounds. (For the given parameter values, no partially revealing equilibrium exists for $F < 7$.)
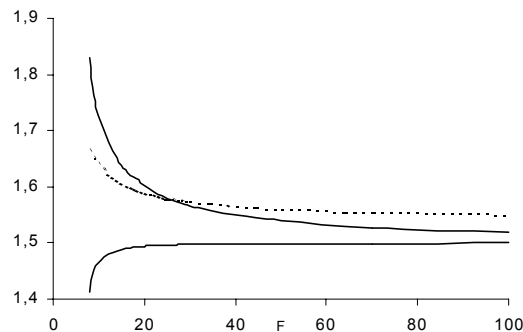
(d)

Apparently, comparative static results obtained above for (x_h, y_h) continue to be valid for the case that (22) does not hold.

4   Summary and discussion.

This paper starts from the stylised fact that policymakers publish their information only selectively: A central bank tends not to predict a recession, and the IMF is unlikely to forecast a currency crisis. The paper then searches for circumstances in which such a partially revealing reporting rule can be part of a (sequential) equilibrium of a static signalling game in which market participants (the receivers) take the policymaker's reporting strategy into account when evaluating his report.

With the aim to explicitly link the policymaker's target function to social welfare, the economic framework in which partially revealing reporting rules are analysed is a par-

tial equilibrium model of an imperfectly competitive economy, in which firms Cournot-compete for customers when demand is uncertain. In the cases for which results have already been obtained, the equilibrium reporting rule satisfies the following properties: Extreme news is withheld, and intermediate news published. In addition, the higher the policymaker's incentive is to increase production (i.e., the less competitive the economy is), the worse the worst news he makes public; the better the best news he makes public; the lower firms' expectation of the news he withholds; and the better the average news he publishes.

The most unorthodox assumption made to ensure existence of a partially revealing equilibrium is that policymaker and firms agree to disagree on the informational value of the policymaker's private information; more specifically: the assumption that the policymaker thinks that markets would overreact to his piece of information. Section 3.1 contains a justification. Keeping in mind that information can only be credibly withheld if the policymaker's preferences are not monotone in the market's action, it appears difficult to imagine a situation in which policymaker and market agree on the importance of a piece of information, and nevertheless the policymaker finds it optimal to withhold extreme news. (Comments very welcome.) All in all, it seems that any analysis of the social benefits of making information public has to be executed very carefully once it seems reasonable to assume that market participants are aware of the existence of the information.[11]

The model is restrictive in that it assumes that firms do not receive private information about the state of the economy. If they do, the policymaker cannot predict aggregate capacity Q without error. Welfare is concave in Q (cf. eq. (2)), and thus, variance reduces welfare. The policymaker's signalling strategy now not only influences firms' mean estimate of the demand. In addition, the variance of economic activity is affected, which decreases welfare. Publishing the signal reduces the variance by more than withholding it. Consequently, one would expect that in a model in which firms receive private information about the economy, the policymaker has a relatively stronger

---

[11]In the context of coordination games, Morris and Shin (2002) derive such welfare results, assuming that agents are unaware of the existence of the information if it is withheld.

preference for making his signal public.

Another dimension in which the model is restrictive is that it does not allow the policymaker to send a biased signal: Forecasts are particularly difficult to verify, and thus it may not be appropriate to consider information to be certifiable. Crawford and Sobel (1982) show that in this case, more information is transmitted when players' interests are close. More specifically, different senders must have different preference orderings over the receivers action. It is conjectured that neither in the setup of section 2.4, nor in the one of section 3, a credible strategy would exist. In section 2.4 all policymaker types have an incentive to send a signal (slightly) above their type, attempting to induce their target level of activity. In section 3, all types would always announce that their type is equal to their common posterior estimate of the demand intercept. Thus, no signal would be credible.

A dynamic structure would offer the possibility to study a policymaker's signalling behaviour if market participants simultaneously learn about the precision of the policymaker's research, and the bias in his publication. In this framework, lying would be costly for the policymaker in that it would also reduce market's estimate for the precision of his research. This, in turn, would reduce his ability to influence the market's behaviour in extreme circumstances. However, the basic problem of having to construct an incentive for not communicating all information to the market appears to remain.

Finally, one could allow the policymaker to directly influence the economy, e.g., through interest-rate setting, extending credit to countries to enable them to fight off a currency crises, or through purchases of goods in the case of a fiscal policy authority. In this case, the publication of research results could carry additional informational value in that they help predict a policymaker's future action.

5   References

Cooper, Russel W. (1998), *Coordination Games - Complementarities in Macroeconomics*, Cambridge University Press: Cambridge, UK.

Morris, Stephen and Hyun Song Shin (2000), *Global games*, Invited paper for the

Eighth World Congress of the Econometric Society, Seattle.

Morris, Stephen and Hyun Song Shin (2002), Social value of public information, *American Economic Review* 92 (5), 1521-1534.

Milgrom, Paul (1981), Good news and bad news: Representation theorems and applications, *Bell Journal of Economics* 12 (2), 380-391.

Seidmann, Daniel J. and Eyal Winter (1997), Strategic information transmission with verifiable messages, *Econometrica* 65 (1), 163-169.

Vives, Xavier (1999), Oligopoly Pricing: Old ideas and New Tools, MIT Press.

6 Appendix: Necessary conditions of Seidmann and Winter (1997)'s full revelation result

If firms and policymaker share the same prior about the importance of the signal the policymaker receives, all the conditions of Seidmann and Winter (1997)'s result are fulfilled and one obtains full disclosure in the unique sequential equilibrium:

- The policymaker's utility is strictly concave and the firms' utility is weakly concave in the demand intercept a;

- their preferred action is differentiable and strictly increasing in a;

- the single-crossing property is fulfilled: if a lower type t' weakly prefers a higher action $q'' > \hat{q}(t') = \tau(t') - c$ to a lower action $q' < \hat{q}(t')$, then a higher type t'' strictly prefers q'' over q'

- there is a worst-case inference for each closed set of types. (That is, for each closed subset of types, there is a type which *no* type in the subset wants to be mistaken for. In this paper, this is simply the lowest type in each subset.)

- For all types, the sender's preferred action is above the receiver's preferred action. (The policymaker always prefers a higher capacity provision than the firm in an imperfectly competitive economy.)