Central bank's stabilization and communication policies when firms have motivated overconfidence in their own information accuracy or processing

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- Motivated beliefs, by generating overconfidence, **affect** the way firms' managers set their **prices**.

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We show that **the presence of motivated beliefs has stark consequences for the conduct of optimal stabilization and communication policies**.

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- Firms accordingly **rely too much on private information** to set their price, which can **raise price dispersion** and deteriorate welfare.

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- Beauty contest with heterogeneous and dispersed information
- Central bank's monetary policy under heterogeneous and dispersed information
- Motivated and subjective beliefs

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- Motivated and subjective beliefs
  - Bénabou & Tirole (2016): motivated reasoning
  - Banerjee et al. (2020): introduction of motivated beliefs in Angeletos & Pavan (2007)
  - Benigno & Karantounias (2019), Broer & Kohlhas (2019): overconfidence bias in macro under dispersed information

Main results

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Communication and stabilization policies

- Objective beliefs (James & Lawler, 2011): opacity with full stabilization is optimal.
  By taking an action that is hidden from the public, the central bank succeeds in stabilizing the economy without inducing agents to make an inefficient use of information.
- Motivated beliefs about capacity to process own private info or central bank disclosures: ***optimal intermediate levels of transparency and stabilization***.

The economy (variant of Adam (2007)) - Representative household

The representative household maximizes its **utility** in (C, L)

$$\frac{(\Theta C)^{1-\xi}}{1-\xi} - \Theta L,$$

where C: consumption of composite good is a CES aggregate of continuum of differentiated products, L: labor supply, Θ: random variable featuring **labor supply shocks** ($\mathbb{E}(\Theta) = 1$), ξ: coefficient of relative risk aversion.

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FOC: the marginal rate of substitution of leisure for consumption is equal to the real wage

$$(\Theta C)^{\xi} = \frac{W}{P},$$

which determines C, and L is computed by inserting C in the budget equation.

The economy - Representative household

The consumer minimizes the expenditure $\int_0^1 P_i C_i di$ required to ensure a volume C of consumption:

$$C_i = \left(\frac{P_i}{P}\right)^{-s} C, \text{ with } P = \left(\int_0^1 P_i^{1-s} di\right)^{\frac{1}{1-s}},$$

where $s > 1$: constant elasticity of substitution between the differentiated goods (substitutable goods), P: price index of all differentiated goods, so that $PC = \int_0^1 P_i C_i di = Z$, the nominal expenditure (under the control of the central bank).

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Without symmetry across firms, the arithmetic mean $L = \int_0^1 C_i di$ of the output of all firms is higher than the mean $C = \left(\int_0^1 C_i^{\frac{s-1}{s}} di\right)^{\frac{s}{s-1}}$.
$\Rightarrow$ *Dispersion of the output levels across firms will be detrimental to the representative household as the same level of consumption requires more labor.*

The economy - Firms

Firm $i \in [0,1]$ **does not observe** Θ and **sets price** P_i to maximize expected real profit, conditional on information set Γ_i:

$$\mathbb{E}\left[\left(\left(\frac{P_i}{P}\right)^{1-s} - (\Theta C)^{\xi}\left(\frac{P_i}{P}\right)^{-s}\right) C \middle| \Gamma_i\right].$$

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Given some realization of the fundamental θ, setting a price p_i that differs from $\widehat{p} \equiv \arg\max_{p_i} \tilde{\pi}\left(p_i - p, c + \theta\right) = p + \xi\left(c + \theta\right)$ leads to the **profit loss**:

$$\tilde{\pi}\left(\widehat{p} - p, c + \theta\right) - \tilde{\pi}\left(p_i - p, c + \theta\right) = \frac{s-1}{2}\left(p_i - \widehat{p}\right)^2,$$

where lower case letter denotes the log-deviation of the variable, and $\tilde{\pi}$ is the second order Taylor approximation of the real profit function.

Price dispersion increases the aggregate profit loss.

The economy - Firms

Firm i sets a price maximizing its **expected** profit:

$$p_i = \mathbb{E}_i\left[\widehat{p}\right] = (1-\xi)\,\mathbb{E}_i\left[p\right] + \xi\mathbb{E}_i\left[z+\theta\right], \text{ with } \mathbb{E}_i \equiv \mathbb{E}\left[\cdot\middle|\,\Gamma_i\right],$$

where $z = p + c$ is the log-deviation of the nominal aggregate expenditure.

The expected profit maximizing price is a convex combination of the expected mean price, reflecting a **coordination motive**, and of the expected sum of the fundamental and policy deviations, reflecting a **fundamental motive**.

$\xi < 1$: prices are strategic complements.

The economy - The central bank

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Welfare function (approximated at the second order and neglecting a constant):

$$V\left(\sigma_{\mathbf{p}}^2\right) = -\frac{s\xi - 1}{\xi}\left(\frac{\sigma_{\mathbf{p}}^2}{2}\right) - \frac{1}{2}\left(\frac{(s-1)(3s\xi - 1)}{\xi^2} + s^2\right)\left(\frac{\sigma_{\mathbf{p}}^2}{2}\right)^2.$$

We assume that $s\xi \geq 1$, so that V is a decreasing function of $\sigma_{\mathbf{p}}^2$.

$\Rightarrow$ The objective of the central bank is to **minimize price dispersion** $\sigma_{\mathbf{p}}^2$.

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- **Pure communication** ($z = 0$)
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- **Communication and stabilization**
  The central bank takes an action and discloses information. It sets $z = -\rho y$, where $\rho \in [0, 1]$ is the value of the policy instrument and it chooses σ_ϕ^2.

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σ_ϕ^2 is under the **control of the central bank**.

Under transparency, y is a public signal.
Under opacity ($\sigma_\phi^2 \to \infty$), the central bank disclosure does not contain any valuable information.

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- $\delta = 1$: rational expectations,
- $\delta > 1$: firm i **overweights** the private information when forming expectations, meaning that it believes the signal to contain **less** noise than it objectively contains,
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Subjective beliefs are **motivated** by making firm i **choose its preferred value of** δ minimizing its expected profit loss, resulting from a price set on the basis of its subjective belief δ and of its information (x_i, y_i) yet to come.

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- The cost function $\mathcal{C}$ is assumed to be strictly quasi-convex with a minimum equal to zero at $\delta = 1$, hence increasing (resp. decreasing) for $\delta > 1$ (resp. $\delta < 1$)
- The weight ψ is assumed to be **increasing in the relative precision of the information that is subjectively considered by firms** (so depending on the type of motivated beliefs: $\left(\sigma_\eta^2 + \sigma_\phi^2\right)/\sigma_\varepsilon^2$ or $\sigma_\eta^2/\left(\sigma_\varepsilon^2 + \sigma_\phi^2\right)$).

  Idea behind this assumption: *subjectively assessing an information that will not be used is less costly than subjectively assessing an information that will be used*.

Motivation of beliefs

The sign of the derivative of $\mathcal{L}(\boldsymbol{\delta}) + \psi\mathcal{C}(\boldsymbol{\delta})$ with respect to δ is -1 if $\delta \leq 1$, otherwise

$$\text{sgn}\left(\frac{d\mathcal{L}(\boldsymbol{\delta})}{d\delta} + \psi\frac{d\mathcal{C}(\boldsymbol{\delta})}{d\delta}\right) = \text{sgn}\left(-\frac{1}{\delta^2} + \psi\right),$$

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For convenience, we assume:

i) when firms form motivated beliefs about their private information

$$\psi = \left(\beta\frac{\sigma_\eta^2 + \sigma_\phi^2}{\sigma_\varepsilon^2}\right)^{2\alpha}$$

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The **equilibrium subjective belief** is given by $\delta^* = 1/\min\left(\sqrt{\psi}, 1\right)$, so that firms may exhibit **overconfidence**.

Equilibrium in linear price strategies

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At a **symmetric equilibrium**, we can identify:

$$\begin{aligned}
\kappa_1 &= \lambda - \rho\nu = \frac{(1-\rho)\,\sigma_\varepsilon^2/\delta_\varepsilon - \rho\xi\sigma_\eta^2}{\xi\sigma_\eta^2 + \sigma_\phi^2/\delta_\phi + \sigma_\varepsilon^2/\delta_\varepsilon} \equiv \kappa_1(\boldsymbol{\delta}), \text{ with } \boldsymbol{\delta} = (\delta_\varepsilon, \delta_\phi), \\
\kappa_2 &= (1-\lambda) - \rho(1-\nu) = \frac{\xi\sigma_\eta^2 + (1-\rho)\,\sigma_\phi^2/\delta_\phi}{\xi\sigma_\eta^2 + \sigma_\phi^2/\delta_\phi + \sigma_\varepsilon^2/\delta_\varepsilon} \equiv \kappa_2(\boldsymbol{\delta}), \\
\kappa_0 &= -\frac{s-1}{2}\frac{1-\xi}{\xi}\left(\kappa_1^2\sigma_\phi^2 + \kappa_2^2\sigma_\varepsilon^2\right) \equiv \kappa_0(\boldsymbol{\delta}).
\end{aligned}$$

$\kappa_1(\boldsymbol{\delta}) + \kappa_2(\boldsymbol{\delta}) = 1 - \rho.$

Central bank policy

Recall welfare is decreasing in $\sigma^2_{\mathbf{p}}$, which we can now express as:

$$\sigma^2_{\mathbf{p}} \simeq \kappa_1^2 \sigma^2_\phi + \kappa_2^2 \sigma^2_\varepsilon.$$

Welfare depends directly upon the central bank communication instrument σ^2_ϕ and indirectly, through the coefficients κ_1 and κ_2, again on σ^2_ϕ but also on central bank stabilization instrument ρ.

Recall:

$$\begin{aligned} \kappa_1 &= \frac{(1-\rho)\,\sigma^2_\varepsilon/\delta_\varepsilon - \rho\xi\sigma^2_\eta}{\xi\sigma^2_\eta + \sigma^2_\phi/\delta_\phi + \sigma^2_\varepsilon/\delta_\varepsilon} \\ \kappa_2 &= \frac{\xi\sigma^2_\eta + (1-\rho)\,\sigma^2_\phi/\delta_\phi}{\xi\sigma^2_\eta + \sigma^2_\phi/\delta_\phi + \sigma^2_\varepsilon/\delta_\varepsilon} \end{aligned}$$

Central bank policy - Pure communication

- **Objective belief:** $\sigma_\phi^{2\,*} = 0$
  Transparency ($\sigma_\phi^2 = 0$) $\Rightarrow \uparrow$ Reliance on central bank's public signal y
  ($\uparrow \kappa_1, \downarrow \kappa_2$) $\Rightarrow \downarrow$ Price dispersion $\Rightarrow \uparrow$ Welfare

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- **Motivated belief on ability to process information:** ***robustness of*** $\sigma_\phi^{2\,*} = 0$
  Transparency $(\sigma_\phi^2 = 0) \Rightarrow \uparrow$ Precision of subjectively assessed information $\Rightarrow \uparrow$ Cost for firms of mistakenly believing they are able to process information $(\uparrow \psi) \Rightarrow \uparrow$ Reliance on objective beliefs $(\delta \to 1)$ and on y $(\uparrow \kappa_1) \Rightarrow \downarrow$ Price dispersion $\Rightarrow \uparrow$ Welfare

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- **Motivated belief on private information precision *may reverse optimality of transparency*** (under a low but sensitive weight on the cost of being irrational)
  Transparency ($\sigma_\phi^2 \to 0$) $\Rightarrow \downarrow$ Relative precision of subjectively assessed private information $\Rightarrow \downarrow$ Cost of mistakenly believing their x_i is very precise (if α large and β small) ($\downarrow \psi$) $\Rightarrow \uparrow$ Overconfidence in precision of x_i ($\uparrow \delta_\varepsilon$) $\Rightarrow \uparrow$ Reliance on x_i ($\uparrow \kappa_2$) $\Rightarrow \uparrow$ Price dispersion $\Rightarrow \downarrow$ Welfare

Central bank policy - Pure communication

Central bank policy under motivated beliefs about the quality of private information ($\delta_\varepsilon = \delta$ and $\delta_\phi = 1$): reversal of the case for transparency

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Central bank policy under motivated beliefs about the quality of private information ($\delta_\varepsilon = \delta$ and $\delta_\phi = 1$): reversal of the case for transparency

Recall price dispersion: $\sigma_{\mathbf{p}}^2 = (1-\kappa_2)^2 \sigma_\phi^2 + \kappa_2^2 \sigma_\varepsilon^2$.

If $\alpha\xi > 1$, the derivative is negative for σ_ϕ^2 and ψ both small enough:

$$\lim_{\sigma_\phi^2 \to 0} \operatorname{sgn}\left(\frac{\partial \sigma_{\mathbf{p}}^2}{\partial \sigma_\phi^2}\right) = \operatorname{sgn}\left(\left(\beta \sigma_\eta^2/\sigma_\varepsilon^2\right)^\alpha - \frac{2\xi\left(\alpha\xi - 1\right)}{\xi + \beta^\alpha \left(\sigma_\eta^2/\sigma_\varepsilon^2\right)^{\alpha-1}}\right) = -1$$

if β and/or $\sigma_\eta^2/\sigma_\varepsilon^2$ are low enough.

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if β and/or $\sigma_\eta^2/\sigma_\varepsilon^2$ are low enough.

$\rightarrow$ **A combination of a high value of α and a small value of β** (a low but sensitive weight on the cost of being irrational) **destroys the optimality of a fully transparent communication policy**.

Since $\sigma_{\mathbf{p}}^2$ is decreasing in σ_ϕ^2 when $\sigma_\phi^2 \to 0$, we get an **interior solution** to the minimization of $\sigma_{\mathbf{p}}^2$ in terms of σ_ϕ^2.

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Central bank policy under motivated beliefs about the quality of private information ($\delta_\varepsilon = \delta$ and $\delta_\phi = 1$): intuition for an optimal interior degree of transparency

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Detrimental effect of opacity on price dispersion:
$\sigma_\phi^2 \to \infty \Rightarrow \uparrow$ Precision of subjectively assessed information $\Rightarrow \uparrow$ Cost for firms of being irrational ($\uparrow \psi$) $\Rightarrow \uparrow$ Reliance on objective beliefs ($\downarrow \delta_\varepsilon$) and on x_i ($\uparrow \kappa_2$) $\Rightarrow \uparrow$ Price dispersion $\Rightarrow \downarrow$ Welfare.

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Intermediate level of transparency balances the benefit of increasing firms' information on θ (making them rely less on private info) **and the detrimental effect of firms' overconfidence**:

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Intermediate level of transparency balances the benefit of increasing firms' information on θ (making them rely less on private info) **and the detrimental effect of firms' overconfidence**:

- by not being fully transparent, the central bank imposes a larger cost on overconfidence in precision of private info,
- by not being fully opaque, the central bank makes firms more informed and less depend on private info.

Central bank policy - Communication and stabilization

- **Objective belief:** $(\sigma_\phi^{2*} \to \infty, \rho^* = 1)$

  Opacity $(\sigma_\phi^2 \to \infty)$ and full stabilization $(\rho = 1) \Rightarrow \downarrow$ Reliance on public signal y_i $(\kappa_1 = 0)$ **and** $\downarrow$ **Reliance on private info** x_i $(\kappa_2 = 0) \Rightarrow \downarrow$ Price dispersion $\Rightarrow \uparrow$ Welfare

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- **Motivated belief on private information precision:** ***robustness of*** $({\sigma_\phi^2}^* \to \infty, \rho^* = 1)$
  Opacity $(\sigma_\phi^2 \to \infty)$ and full stabilization $(\rho = 1) \Rightarrow \uparrow$ Relative precision of subjectively assessed info $(\kappa_1 = 0)$ **but also** $\downarrow$ **Reliance on private info** $(\kappa_2 = 0) \Rightarrow \downarrow$ Price dispersion $\Rightarrow \uparrow$ Welfare

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- **Motivated belief on ability to process information *may reverse the optimality of opacity and full stabilization*** $(\alpha \geq 1)$

  Opacity $(\sigma_\phi^2 \to \infty)$ and full stabilization $(\rho = 1) \Rightarrow \downarrow$ Relative precision of subjectively assessed info $\Rightarrow \downarrow$ Cost for firms of mistakenly believing they are able to process info (if $\alpha \geq 1$) $\Rightarrow \uparrow$ Overconfidence in ability to process info $\Rightarrow \uparrow$ Reliance on public **and private** info $\Rightarrow \uparrow$ Price dispersion $\Rightarrow \downarrow$ Welfare

Central bank policy - Communication and stabilization

Central bank policy under motivated beliefs about the ability to process information ($\delta_\varepsilon = \delta_\phi = \delta$): optimal intermediate degree of communication and stabilization policies

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Central bank policy under motivated beliefs about the ability to process information ($\delta_\varepsilon = \delta_\phi = \delta$): optimal intermediate degree of communication and stabilization policies

By optimally setting an interior degree of transparency and an intermediate level of stabilization policy, the central bank **balances the benefit of increasing firms' information** on θ (making them rely less on private info) **and the detrimental effect of firms' overconfidence**.

Central bank policy - Communication and stabilization

Central bank policy under motivated beliefs about the ability to process information ($\delta_\varepsilon = \delta_\phi = \delta$): optimal intermediate degree of communication and stabilization policies

By optimally setting an interior degree of transparency and an intermediate level of stabilization policy, the central bank **balances the benefit of increasing firms' information** on θ (making them rely less on private info) **and the detrimental effect of firms' overconfidence**.

Since switching from (i) motivated belief on private info precision to (ii) motivated belief on ability to process info **reverses the sense of dependence of ψ wrt central bank's instrument σ_ϕ^2**, the rationale for this result is the same as the one for pure communication under (i).

Conclusion

- Under pure communication, motivated beliefs about own private information reverse the corner, bang-bang, solution of transparency, found in the literature under objective beliefs and lead to **intermediate levels of communication policy**.
- Under communication and stabilization policies, motivated beliefs about own abilities to process information reverse the corner, bang-bang, solution of opacity with full stabilization found in the literature under objective beliefs and lead to **intermediate levels of communication and stabilization policies**.

Conclusion

- Under pure communication, motivated beliefs about own private information reverse the corner, bang-bang, solution of transparency, found in the literature under objective beliefs and lead to **intermediate levels of communication policy**.
- Under communication and stabilization policies, motivated beliefs about own abilities to process information reverse the corner, bang-bang, solution of opacity with full stabilization found in the literature under objective beliefs and lead to **intermediate levels of communication and stabilization policies**.

$\Rightarrow$ It is important to **evaluate the strengh of information frictions and the type of motivated beliefs** that dominates to formulate stabilization and communication policies in an appropriate manner.

Thank you.

Appendix - Timing

1. Based on the laws of distribution of signals y and x_i, the central bank chooses the value of one or both of the two policy instruments: σ_ϕ^2 and/or ρ.
2. Based on the laws of distribution of public and private information, and the values of the policy instruments, each firm i adopts its subjective belief concerning either (i) the quality of its private information ($\delta_\varepsilon = \delta$, with $\delta_\phi = 1$) or (ii) its ability to treat information in general ($\delta_\varepsilon = \delta_\phi = \delta$). This belief is motivated conditionally on a potential value θ of the fundamental (not yet realized).
3. Nature chooses a realization θ and sends specific noisy signals $y = \theta + \eta$ to the central bank and $x_i = \theta + \varepsilon_i$ to each firm i. The central bank discloses its information, each firm i receiving a signal $y + \phi_i = y + \eta + \phi_i$.
4. Firms set their price on the basis of their signals (x_i, y_i), conditionally on their adopted subjective beliefs δ and on the central bank policy $\left(\sigma_\phi^2, \rho\right)$.
5. The representative household supplies labor and consumes products at the prices set by the firms.

Appendix - Equilibrium in linear strategy

We assume that each firm i sets its price as a linear affine function of the two signals it receives:

$$p_i = \kappa_0 + \kappa_1 y_i + \kappa_2 x_i.$$

We stick to symmetry and suppose that every other firm uses the same triple of coefficients $\overline{\kappa}_0$, $\overline{\kappa}_1$ and $\overline{\kappa}_2$.

Referring to the pricing rule which ensures that firm i sets a profit maximizing price p_i, and computing the expectations $\mathbb{E}_i[p]$, $\mathbb{E}_i[\theta]$ and $\mathbb{E}_i[y]$, we obtain for $z = -\rho y$

$$\begin{aligned} p_i &= (1-\xi)\,\mathbb{E}_i[p] + \xi \mathbb{E}_i[z+\theta] \\ &= (1-\xi)\left(\overline{\kappa}_0 - \frac{s-1}{2}\left(\overline{\kappa}_1^2\sigma_\phi^2 + \overline{\kappa}_2^2\sigma_\varepsilon^2\right)\right) + \left((1-\xi)\,\overline{\kappa}_1 - \xi\rho\right)\mathbb{E}_i[y] \\ &\quad + \left((1-\xi)\,\overline{\kappa}_2 + \xi\right)\mathbb{E}_i[\theta], \end{aligned}$$

Appendix - Explicit cost function

Firms minimize their expected profit loss:

$$\min_{\boldsymbol{\delta}} \underbrace{\mathbb{E}\left(\left(p_i\left(\boldsymbol{\delta}\right)-\widehat{p}\right)^2\middle|\,\theta\right)}_{\mathcal{L}(\boldsymbol{\delta})}+\psi\mathcal{C}\left(\delta\right), \text{with}$$

- the loss function

$$\begin{aligned}\mathcal{L}\left(\boldsymbol{\delta}\right) \quad = \quad & \left(\kappa_0\left(\boldsymbol{\delta}\right)-\left(1-\xi\right)\overline{\kappa}_0+\left(1-\xi\right)\frac{s-1}{2}\left(\overline{\kappa}_1^2\sigma_\phi^2+\overline{\kappa}_2^2\sigma_\varepsilon^2\right)\right)^2 \\ & +\left(\kappa_1\left(\boldsymbol{\delta}\right)-\left(1-\xi\right)\overline{\kappa}_1+\xi\rho\right)^2\sigma_\eta^2+\left(\kappa_1\left(\boldsymbol{\delta}\right)\right)^2\sigma_\phi^2/\delta_\phi \\ & +\left(\kappa_2\left(\boldsymbol{\delta}\right)\right)^2\sigma_\varepsilon^2/\delta_\varepsilon.\end{aligned}$$

- the convenient cost function

$$\mathcal{C}\left(\boldsymbol{\delta}\right)=\begin{cases}\left|\int_1^\delta\left(\kappa_2\left(h,1\right)\right)^2\sigma_\varepsilon^2dh\right| & \text{if } \boldsymbol{\delta}=(\delta,1) \\ \left|\int_1^\delta\left(\left(\kappa_2\left(h,h\right)\right)^2\sigma_\varepsilon^2+\left(\kappa_1\left(h,h\right)\right)^2\sigma_\phi^2\right)dh\right| & \text{if } \boldsymbol{\delta}=(\delta,\delta)\end{cases},$$

which has a global minimum equal to 0 at $\delta=1$ (obj. beliefs) and is increasing (resp. decreasing) for $\delta>1$ (resp. $\delta<1$).

Appendix - Signalling stabilization ($\sigma_\phi^2 = 0$)

The signal sent by the central bank is common knowledge among the firms thanks to the full observation of the stabilization action z. The central bank sets $z = -\rho y$, where $\rho \in [0, 1]$ is the value of the policy instrument.

Since the central bank's stabilization policy is directly observed by firms, the latter can infer the central bank's information on the fundamental shock.

A common knowledge stabilization policy has no effect on welfare because it does not influence price dispersion.

Both under objective and subjective beliefs and whatever the type of motivated beliefs, the **stabilization policy is indeterminate** (and welfare is only influenced by the full disclosure).