Asymmetric Information and Monetary Policy in Common Currency Areas

Laura Bottazzi\textsuperscript{1}       Paolo Manasse\textsuperscript{2}

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\textsuperscript{1}Associate Professor of Economics, Università Bocconi, IGIER and CEPR. Address: IGIER, Via Salasco 5, 20136 Milano, Italy. Email:laura.bottazzi@uni-bocconi.it
\textsuperscript{2}Corresponding Author. Professor of Economics, Università di Bologna and IGIER. Address: Dept. of Economics, Strada Maggiore, 45, 40100 Bologna (Italy), Email:manasse@spbo.unibo.it. We thank Francesca Barigozzi, PierPaolo Battigalli, Paolo Garella and Sandro Brusco for their comments. An anonymous referee provided invaluable suggestions for improving the paper.
Abstract

In a Common Currency Area the Common Central Bank sets a uniform rate of inflation across countries, taking into account the area’s economic conditions. Suppose countries in recession favor a more expansionary policy than countries in expansion: when national business cycles are not fully synchronized a conflict of interest between members arises. If member governments have an informational advantage over the state of their domestic economy, such conflict may create an adverse selection problem: national authorities overemphasize their shocks, in order to shape the common policy towards their needs. This creates an inefficiency over and above the one-policy-fits-all cost discussed in the optimal currency area literature. In order to minimize this extra-burden of asymmetric information, monetary policy must over-react to large symmetric shocks and under-react to asymmetric shocks of different size.

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Authors: Laura Bottazzi, Associate Professor of Econonomics, Università Bocconi, IGIER and CEPR. Address: IGIER, Via Salasco 5, 20136 Milano, Italy. Email:laura.bottazzi@unibo.it

Paolo Manasse, Professor of Economics, Università di Bologna and IGIER. Address: Dept. of Economics, Strada Maggiore, 45, 40100 Bologna (Italy), E-mail:manasse@spbo.unibo.it
1 Introduction

In a common currency area (CCA) national governments delegate monetary policy decisions to a supra-national authority, the Common Central Bank (CCB). The CCB sets a uniform rate of inflation across countries, taking into account the area’s economic conditions. Suppose that countries in recession favor a more expansionary policy than countries in expansion\(^1\). Then if national business cycles are not fully synchronized, a conflict of interest between members arises. When governments of member countries have an informational advantage over the state of their domestic economy, such conflict may create an adverse selection problem: national authorities overemphasize their shocks in order to shape the common policy towards their needs. Ignoring the problem can be extremely costly, since the CCB may end up inappropriately implementing ”stop and go” policies that add to inflation variability. This informational problem magnifies the one-policy-fits-all inefficiency discussed in the optimal currency area literature. The paper’s main result is that, in a currency area with asymmetric information, the optimal monetary policy must over-react to large symmetric shocks and under-react to asymmetric ones of unequal size. Overall, asymmetric information aggravates the problem of tailoring the policy response to the state of the union’s economy, and causes a welfare loss that is increasing in the number of member countries. We also show that disregarding some of the information reported by national authorities and adopting a ”rule of thumb” is never efficient, although this rule closely mimics the optimal rule when large shocks are either very rare or very frequent.

The paper’s central idea is that there is an important information asymmetry between policymakers in different countries as to what they know about domestic macroeconomic conditions. This can give rise to outright misrepresentation of statistics (for example a country might misreport its unemployment rate, see below), misinterpretation of statistics (for example national policymakers might be better placed than their foreign counterparts to judge the implications of labor market outcomes on the deviation of output from trend),

\(^1\)This may be due to the existence of constraints on using domestic policy instruments for stabilization purposes. For example, balanced budget rules, borrowing ceilings, limited international redistribution schemes are frequent in currency unions between developed countries. Alternatively, the constraints may originate from insufficient domestic savings and limited access to international capital markets, as is often the case in developing economies.
deliberate lack of transparency about the information sources, gathering process, and timeliness of release of statistics (these issues are covered by the IMF surveillance procedure under the heading of Report On Observance of Standard and Codes (ROSC)\(^2\))

In his presidential address to the International Statistical Institute, Felligi (1989)[12] raises the issue quite clearly:

"..Statistical information is a product with peculiar attributes. One of them is that users are seldom in a position to check its quality directly. Yet data that are not trusted are clearly of little utility, whatever their intrinsic quality".

The case of the rate of unemployment in the UK is quite suggestive. In the 80’s British labor economists have been bewildered by the ever-changing definition of unemployment. Paul Gregg [14](1994) recalls that

"..Charges against the count method of estimating unemployment have concerned allegations about politically inspired manipulation of the figures through numerous changes in coverage during the 1980s. The supporting evidence for these changes is that all but one of these changes have been unidirectional-downwards. Critics have expressed a view that calculating unemployment on the old (pre-1982) coverage would result in a considerably higher total figure."

\(^2\)Quoting the IMF website, “ROSCs summarize the extent to which countries observe certain internationally recognized standards and codes. The IMF has recognized 11 areas and associated standards as useful for the operational work of the Fund and the World Bank. These comprise data; monetary and financial policy transparency; fiscal transparency; banking supervision; securities; insurance; payments systems; corporate governance; accounting; auditing; and insolvency and creditor rights”.

\(^3\)According to Bartholomew at al.(1995)[2] “...in the 1970s, the figure for unemployment broadly related to those receiving unemployment benefits, plus those who did not receive benefits but registered themselves regularly for possible work. Increasingly during the early 1980’s the latter group was excluded from the count and the former group was tightened up. For example, in 1981, some 195000 individuals were struck off the count by the removal of those in training or in temporary work; in 1982, a further 216000 individuals were struck off when benefit claimants only were included in the figures; in 1983, some 107000 men who were over 60 years of age, not working and not entitled to benefits or credits, were similarly struck off the count. An important consequence of these and other changes was the unease expressed by the general public about what the published figures actually meant and how the changes, which occurred both up or down, could be effectively assessed".
Lack of confidence in the figures became so serious that a government Working Party was set up to analyze the question: according to the ensuing official report,

"The level of unemployment in a country is a key indicator of economic and social well-being. The UK figures published monthly are eagerly awaited and hotly debated. Recently, and especially during the early part of 1994, debate became intense and it was claimed, on behalf of the Opposition, that the figures were worthless. It was implied that they were manipulated by the government for its own political ends. This matter is of great concern for Society..." (Bartholomew, Moore, Smith, Allin 1995)[2]

We think that these informational problems are potentially more serious at the international level, for arrangements such as currency unions and federal redistribution schemes. In this spirit, Bordignon, Manasse and Tabellini (2001) [5] argue that

"...in the European Union or in countries such as Russia and China (Laffont 1995 [15])..., national or regional governments are the primary source of statistical information...while federal authorities are at a disadvantage in assessing the quality of this information" [5].

With the exception of Bottazzi and Manasse (1998) [6] the issue of asymmetric information in common currency areas has received no attention in the literature5. Dixit (2000, p.779) [10], however, mentions this among the ”important extension(s) for future research” in the field of monetary policy in currency unions. Conversely, a large quantity of public economics literature exists, particularly on fiscal federalism, that deals with problems of information. Recent examples include Bordignon, Manasse and Tabellini (2001) [5], who study inter-regional redistribution when tax bases are imperfectly observable by the federal government; Cremer et al. (1995)[9], Bucovetsky et al.(1996)[4], Levaggi (1991)[16] deal with intergovernmental grants under asymmetric information over local preferences; Boadway et al.[3] (1995), Raff and Wilson (1995)[19]and Lockwood (1996)[18] study the issue of public

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4Another example is the elimination of the interest rate on mortgages from the definition of the CPI in 1993 in Britain. This was done in order to prevent inflation form shooting up whenever interest rates were raised. Avinash Dixit jokingly told us about the "Dixit and Goodhart" definition of ”core” inflation: the index covering all goods whose price have not increased (!). Other interesting stories on statistics can be read on the BBC site: http://www.stats.org/statswork/bbc-stats.htm.

5With respect to our previous work, here we do not insist on microfoundations, and change the equilibrium concept from dominant to Bayesian strategies.
goods provision when technology is imperfectly observable. Finally, Laffont[15](1995) studies fiscal arrangements in China.

The plan of the paper is the following. Section 2 presents the model. Section 3 considers the benchmark case of full-information. In Section 4 we extend the set-up to asymmetric information. First we show that the full information policy is not incentive compatible, and we discuss the potential costs of ignoring the problem of information. We then discuss the optimal policy rule. Section 5 briefly discusses some possible extensions of the model, and Section 6 summarizes the main results.

2 The Model

There are two endowment-economies, each populated by an identical representative agent. The agent’s indirect utility function, $W$, depends on inflation $\pi$, and on an output shock, $e$, representing the deviation of output from trend. A negative realization means that the economy is in "recession", a positive one that the economy is in "expansion". The output shocks are independent across countries. We require the indirect utility function $W(\pi,e)$ to have some intuitive properties:

$$W_{\pi}(\pi,e) > 0, W_{e}(0,e) > 0, W_{\pi\pi}(\pi,e) < 0, W_{\pi e}(\pi,e) < 0.$$  \hspace{1cm} (1)

where $W_x(.)$ denotes the partial derivative of $W$ with respect to $x$. The first property captures the positive effects of output on consumption. The second and the third represent the idea that, at a low level inflation, $\pi$ is beneficial; above a certain threshold, however, the benefits peter out and the costs of inflation increase. Notice that, due to the last inequality, a country’s most preferred rate of inflation falls when the state of the economy improves. In the appendix we present a dynamic general equilibrium model of the money-into-the utility-function type, where welfare in steady state exhibits such properties. For this model, adapted from Bottazzi and Manasse(2002)([7]), seigniorage is an efficient way of financing the provision of a public good, when inflation is low. When inflation is high, however, distortions in money demand and declining marginal utility of the public good set in, and reduce welfare. Moreover, in that model the preferred rate of inflation declines with output for the following reason: high output yields high fiscal revenue and reduces the need of seigniorage revenue.
For expositional purposes we assume that the indirect utility function takes the quadratic form
\[ W(\pi, e) = -\frac{1}{2}\pi^2 - e\pi + f(e), \quad f_e > 0, \] (2)
and assume that \( e \) can take a finite number of realizations in the interval \([-s, s], s > 0\) with probabilities \( p(e), \sum_e p(e) = 1 \), expected value \( E(e) = 0 \), and variance \( \sigma_e^2 \). The disturbances across countries, \( e \) and \( e' \) ("the other’s" state), are independent. It will be very convenient to consider the particular case where \( e \) can take only four possible realizations, \([-s, -s/2, s/2, s]\), with equal probability \( p(e) = 1/4 \). Under the assumption\(^6\) of discrete uniform distribution, the shocks have zero mean, and variance \( \sigma_e^2 = (5/8)s^2 \).

3 Full Information

3.1 Monetary Independence

Next we characterize the full information optimal policy when each country has monetary sovereignty. We show that the optimal rule is counter-cyclical.

After the realization of the shock, the national central bank chooses inflation so as to
\[ \max_{\pi} W(\pi, e). \] (3)

The optimal inflation rule is simply given by
\[ \pi(e) = -e. \] (4)

The first-best rule is to run an expansionary policy in bad times and a contractionary policy in good times. We can calculate the expected utility in this benchmark case, as well as the first two moments of inflation\(^7\):
\[ U(\pi(e), e) = \sum_e p(e)W(\pi(e), e) = \frac{\sigma_e^2}{2} = \frac{10}{32}s^2 = 0.312s^2, \] (5)
\[ E(\pi(e)) = \sum_e p(e)\pi(e) = 0, \quad \sigma_\pi^2 = \sigma_e^2 = \frac{20}{32}s^2 = 0.625s^2. \]

\(^6\)We carry on with the more general notation \( p(e) \) since we discuss a more general case later on.

\(^7\)We normalize the \( f(e) \) function so that \( \sum_e p(e)f(e) = 0 \).
In the benchmark of monetary independence the average inflation rate is zero, and its variability exactly matches that of the "fundamentals".

3.2 CCA under Full Information

Next we describe the optimal policy in a CCA when the two states $e, e'$ are fully observable. We show that the standard inefficiency of the Optimal Currency Area literature arises because of the impossibility to tailor the common policy to individual needs. In a Common Currency Area, monetary policy is set by the common central bank, the CCB, which chooses a common inflation rate, after observing the realizations of the shocks in the two countries. Thus the CCB solves

$$\max_{\pi} (W(\pi, e) + W(\pi, e')).$$

The optimal policy rule is

$$\pi^{E}(e, e') = -\frac{e + e'}{2}. \quad (7)$$

What matters now is the aggregate (mean) state of the economy. This rule has some intuitive properties: i) it treats both types equally (it is "fair"), $\pi^{E}(e, e') = \pi^{E}(e', e)$; ii) it is symmetric, $\pi(e, e') = -\pi(-e, -e')$; iii) it is non-increasing in the shocks, $\pi^{E}_{e}(e, e') \leq 0$, so that inflation is not raised when more favorable shocks are reported, and iv) it coincides with the first-best rule when shocks are identical, $\pi^{E}(e, e) = \pi(e)$. The last two properties show the nature of the conflict of interest between countries, when shocks differ: the country experiencing a recession ("boom") favors a looser (tighter) monetary policy than the one implemented by the CCB: $\pi(e') > \pi^{E}(e, e') > \pi(e)$ for $e > e'$. Thus the rule gives rise to the standard inefficiency of currency unions, the one-policy-fits-all, whenever shocks are asymmetric. We can compare the two regimes by computing welfare:

$$U(\pi^{E}(e, e'), e) = \sum_{e} \sum_{e'} p(e)p(e')W(\pi^{E}(e, e'), e) = \frac{5}{32}s^2 = 0.156s^2, \quad (8)$$

$$E(\pi^{E}(e, e')) = \sum_{e} \sum_{e'} p(e)p(e')\pi^{E}(e, e') = 0, \quad \sigma_{\pi^{E}}^{2} = \sigma_{e}^{2}/2 = \frac{10}{32}s^2 = 0.312s^2. \quad (8)$$
Compared to the regime of Monetary Independence, the CCA reduces welfare consider-
ably. The loss does not stem from the average level of inflation, which is the same in the
two regimes, but from the inability to tailor the policy response to the shocks. Since these are
assumed to be independent, the policy rule cannot match the variability of the state of each
individual economy. This is the standard loss of an independent policy tool for stabilization.

4 Asymmetric Information

Suppose now that both governments have some private information regarding the state of
their own economy: the domestic government observes $e$ but not $e'$, and vice versa the foreign
one. The CCB cannot verify either one. In such circumstances, the policy rule of the CCB
must be contingent on the states reported by the two governments, $\tilde{e}, \tilde{e}'$. Each government
may try to exploit its informational advantage in order to induce the CCB to choose a policy
that better fits the state of its own economy. If the CCB ignores this incentive, it ends up
choosing the "right" policy for the "wrong" state. Therefore, she must design a policy rule
such that truthful revelation occurs. Next we show that, in order to "separate" the types
and extract the correct information, the rule must over-react to large symmetric shocks and
under-react to small asymmetric ones.

4.1 The game

Let’s be more precise about the game being played. The timing is the following. In stage
1 the CCB designs a policy rule $\pi(\tilde{e}, \tilde{e}')$ that depends on the reports. In stage 2 the shocks
are realized, but only national governments observe national realizations. In stage 3, given
the policy rule, countries simultaneously choose a report in order to maximize their own
expected utility, where the expectation is taken over the other country’s report. Finally, the
CCB implements the rule according to the reported states.

The optimal reporting strategy of "type" $e$, $R(e, \pi(\tilde{e}, \tilde{e}'))$ consists in choosing the state to

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8The numbers in the example must be treated with caution, since they rely on the normalization
$\sum p(e) f(e) = 0$. 

7
report, \( \tilde{e} \), so as to maximize his own expected utility, taking the expectations over the other country's report:

\[
R(e, \pi(\tilde{e}, \tilde{e}')) = \arg \max_{\tilde{e}} E_{\tilde{e}} W(\pi(\tilde{e}, \tilde{e}'), e),
\]

(9)

where \( E_{\tilde{e}} \) denotes type \( e \) expectation of the other country's report, \( \tilde{e} \). An equilibrium with truthful revelation is defined as a set of reports \( \tilde{e}, \tilde{e}' \) and policy rule \( \pi(\tilde{e}, \tilde{e}') \), such that i) given the policy rule, each country chooses an optimal report, \( R(.) \); ii) reports are truthful, \( R(e, \pi(\tilde{e}, \tilde{e}')) = e \); and iii) the policy rule is optimal, in the sense that it maximizes expected welfare:

\[
\pi(\tilde{e}, \tilde{e}') = \arg \max_{\pi} U(\pi(\tilde{e}, \tilde{e}'), e) + U(\pi(\tilde{e}, \tilde{e}'), e').
\]

(10)

The policy can be viewed as a contract that the two parties (the governments) sign before the realization of the shocks. The contract describes the rate of inflation that the CCB must implement in all possible contingencies.

### 4.1.1 Incentives to lie

Here we show that the second-best rule \( \pi^E(.) \) (7) does not induce truth-telling, i.e. it is not incentive-compatible. Intuitively, given this rule, each country is tempted to overemphasize its shock, so as to pull the rate of inflation closer to its most preferred rate \( \pi(e) \). But then, if the governments systematically lie to the CCB, and CCB insists on applying \( \pi^E \), the consequence is a sharp drop in welfare. The CCB can do better, but at the cost of introducing some distortions in her policy rule.

To see this, first we need to calculate the optimal report when the rule \( \pi^E(.) \) is implemented. Having observed the realization of his own state, type \( e \) chooses his report by forming an expectation on \( \tilde{e}' \). We can write a country expected welfare\(^9\) as

\[
E_{\tilde{e}} W(\pi, e) = -\frac{1}{2} E_{\tilde{e}}[\pi]^2 - \frac{1}{2} Var_{\tilde{e}}[\pi] - eE_{\tilde{e}}(\pi) + f(e).
\]

where \( E_{\tilde{e}} \) is the country's expectation of the other's report, \( \tilde{e}' \), \( Var_{\tilde{e}}[\pi] \) is the variance with respect to the same expectation, and \( e \) is known. Equation (7) implies that \( Var_{\tilde{e}}[\pi] \)\(^8\)

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\(^8\)We thank an anonymous referee for suggesting this leaner way to prove the result.
is independent of the country’s own report, \( \tilde{e} \), while the symmetric structure of the set-up implies that \( E_{\tilde{e}}(\tilde{e}') = 0 \). Thus the country can choose \( \tilde{e} \) to maximize \(- (1/2)(-\tilde{e}/2)^2 - e(-\tilde{e}/2)\), which yields \( \tilde{e} = 2e \).

In words, when the policy \( \pi^E \) is followed, both reports will ”exaggerate” the shock, whenever possible. Those who indeed experience the extreme states, \( \pm s \), are constrained to report the truth, since \( e = \pm 2s \) simply does not exist. Moreover, types \( \pm s \) have no scope for under-reporting: if they declare an intermediate state, they end up pushing the CCB in the ”wrong” direction”.\(^{10}\) Conversely, the intermediate types will always lie under the full information rule. The mild-recession type, \( -s/2 \), for example, expects the other to report zero on average, so he knows that if he declares the truth and the CCB follows the rule \( \pi^E(\tilde{e}, \tilde{e}') \), he will get on average \( \pi^E = s/4 \). But this policy is ”too tight” for him: his first best is \( \pi(-s/2) = s/2 > s/4 \). In order to induce the CCB to implement a looser policy, he declares that the economy is experiencing a large recession (and report \(-s\) instead). By so doing (if the CCB believes him) he expects to get away with his first best, \( \pi^E(-s, 0) = \pi(-s/2) = s/2 \). The same argument holds for type \( s/2 \), who will always exaggerate the positive state and report a ”boom” \( s \), in order to get a tighter policy.\(^{11}\)

### 4.1.2 The Dangers of ”Closing the Eyes”

The implication of this is striking: should the CCB ”close her eyes” and adhere to the full information rule when governments cheat, she would end up alternating between extremely loose, \( \pi^E(-s, -s) = s \), and extremely tight, \( \pi^E(s, s) = -s \), policies. With governments cheating, expected welfare \( U^C(\pi^E) \) would fall:

\[
U^C(\pi^E(\tilde{e}, \tilde{e}'), e) = \frac{4}{32}s^2 < U(\pi^E(.) = \frac{5}{32}s^2 , \\
E^C(\pi^E(\tilde{e}, \tilde{e}')) = 0, \quad \sigma^2_{\pi^E} = \frac{16}{32}s^2 > \frac{10}{32}s^2 = \sigma^2_{\pi^E} . 
\]

(11)

In this example, cheating implies a 20% welfare loss with respect to the full information benchmark \((1 - U^C/U^E = 0.2)\). Clearly, this loss stems from the effective adoption of a stop

\(^{10}\)For example, type \(-s\) likes a very expansionary policy \( \pi(-s) = s \), and, if he tells the truth, he expects to get a rate of inflation \( \pi^E = s/2 \) which is lower than desired. However, if he lies and reports, for example, \(-s/2\), he only harms himself, as he manages to induce an even less expansionary policy, \( \pi^E = s/4 \).

\(^{11}\)This argument exploits the fact that \( E\pi^E(.) = \pi^E(E(.) \) due to the linearity of \( \pi^E(.) \).
and go policy that leads to large swings in inflation. The variance of inflation becomes 60% (=16/10-1) larger than under full information.

4.2 The Optimal Policy Under Asymmetric Information

The CCB can do better by designing a policy rule that is incentive compatible. We apply the revelation principle to our game, so that if an equilibrium of the game exists, it must also be a solution to the following problem: the CCB chooses a policy rule that maximizes expected welfare subject to the incentive compatibility constraints.\textsuperscript{12} We assume that the rule must satisfy property iii) of Section 4, namely being "non increasing in the shocks". This guarantees that "extreme" type ±s will never be willing to lie, so that we need only to consider the incentive compatibility constraint of types s/2 (and −s/2). Also, properties i)-ii) of fairness and symmetry turn out to be satisfied by the optimal rule. Formally, this solves Problem 1:

\begin{align}
\max_{\pi(e,e')} & \ U(\pi(e,e'), e) + U(\pi(e', e'), e') \\
\text{s.t.} & \sum_{e'} p(e') W(\pi(s/2, e'), s/2) \geq \sum_{e'} p(e') W(\pi(s, e'), s/2) \\
& \sum_{e'} p(e') W(\pi(- s/2, e'), -s/2) \geq \sum_{e'} p(e') W(\pi(-s, e'), -s/2).
\end{align}

The incentive compatibility constraint (13) states that, under the rule, type s/2 is at least as well off, in expected terms, by reporting s/2 rather than s. A similar interpretation applies to equation (14) for type −s/2. The solution of this problem is simplified by noting that, because symmetry of the optimal rule, \( \pi(e, e') = -\pi(-e, -e') \), either both constraints bind, or neither does. Similarly, the fairness property, \( \pi(e, e') = \pi(e', e) \), implies that we need not write down the two constraints for country \( e' \).\textsuperscript{13} In the Appendix we prove the following proposition:

\begin{itemize}
\item \textsuperscript{12}We do not consider the participation constraint on the basis that there is no possibility of opting out of the CCA. We also assume that the rule cannot be renegotiated.
\item \textsuperscript{13}The first one would read: \( \sum_{e} p(e) W(\pi(e, s/2), s/2) \geq \sum_{e} p(e) W(\pi(e, s), s/2) \)
\end{itemize}

which coincides with the one in the text when \( \pi(e, e') = \pi(e', e) \) holds.
Proposition 1 Let $\pi^S(e',e')$ denote the inflation rule that solves Problem 1. When states of nature are equally likely, $p(e) = 1/4$, all $e$, this policy satisfies the following properties: i) it over-reacts to large symmetric shocks, $\pi^S(-s,-s) = \pi^E(-s,-s) = s$, $\pi^S(s,s) < \pi^E(s,s) = -s$; ii) it under-reacts to asymmetric shocks of different magnitude, $\pi^S(s/2,-s) < \pi^E(s/2,-s) = s/4$, $\pi^S(-s/2,s) > \pi^E(-s/2,s) = -s/4$; iii) the rule coincides with $\pi^E(.)$ in the remaining cases of symmetric shocks $(s/2,s), (-s/2,-s), (s/2,s/2), (-s/2,-s/2)$, and of small asymmetric shocks $(s/2,-s/2)$.

Note that the policy $\pi^S$ is fair ($\pi^S(e,e') = \pi^S(e',e)$) and symmetric ($\pi^S(e,e') = -\pi^S(-e',-e)$). The proposition has an intuitive interpretation. The rule must make the intermediate types indifferent, in expected terms, between reporting the truth and lying. It does so in two ways (see Figure 1). First, in order to discourage extreme (false) reports, it makes inflation so high in symmetric bad states $(-s,-s)$, and so low in good ones $(s,s)$ that only countries who really experience these shocks may want to say so. This explains point $i$).

At the same time, the policy encourages truth-telling by giving rents to the intermediate types in asymmetric states of different size, e.g. $(s/2,-s)$. Here the rule distorts the rate of inflation towards the center, i.e. towards the level preferred by the intermediate types. Notice that the alternative of punishing who reports $-s$ by further raising inflation would not work here, since then type $s/2$ would have an even greater incentive to lie (and report $s$). This explains point $ii$). Finally, the policy does not need to distort the outcomes $(s/2,s/2), (s/2,-s/2), (s/2,s), (-s/2,-s/2), (-s/2,s/2), (-s/2,-s)$, cf point $iii$). Intuitively, the rule aims at making type $s/2$ indifferent, in expected terms, between telling the truth and exaggerating. But there is no need to deviate from the optimal rule, since type $s/2$ is already indifferent between the outcome $(s/2,s/2)$ and a lottery with equally likely outcomes $(s/2,s/2), (s/2,-s/2), (s/2,s)$.

How effective is this rule for limiting the excess burden of asymmetric information? This can be discovered by calculating the value of welfare under the optimal policy\textsuperscript{14}

$$U(\pi^S(e',e),e) = \frac{4.961}{32} s^2 = 0.155 s^2 < U(\pi^E(.)) = \frac{5}{32}s^2,$$

$$E(\pi^S(.)) = 0, \quad \sigma_{\pi^S}^2 = \frac{9.921}{32} = 0.310 s^2 < \frac{10}{32} s^2 = \sigma_{\pi^E}^2.$$  \hspace{1cm} (15)

\textsuperscript{14}We assume that indifference is enough to induce truth telling in the calculation below.
In this example welfare under asymmetric information falls below full information, but just 0.8 percent \( (1 - U^S/U^E) \), compared to the 20 percent loss of the cheating outcome. On one hand, by penalizing ”large” reports, the policy makes sure that these are reported less frequently, i.e. only when they truly occur. On the other, the large induced inflation swings that occur in extreme states are compensated by smaller swings when asymmetric shocks of different size are reported.

4.2.1 Is ”Pooling” (Rule of Thumb) Ever Optimal?

In order to eliminate the incentive to lie of the intermediate type, the optimal rule may in principle be contingent only on a sub-set of the reported information, e.g. the ”sign” (expansion/recession) of the shocks, but not their size (large/small). This possibility is interesting since the optimal policy rule could then be interpreted as a ”rule of thumb”, a rule that picks the same rate of inflation irrespective of whether shocks \( s \) or \( s/2 \) are reported. Next we show that ”pooling” cannot be optimal. By definition the rule of thumb must maximize expected utility (12) and satisfy the constraints

\[
\begin{align*}
\pi(s/2, s) &= \pi(s, s) = \pi(s/2, s/2) = \pi_P^+ \\
\pi(-s/2, -s) &= \pi(-s, -s) = \pi(-s/2, -s/2) = \pi_P^- = -\pi_P^+ \\
\pi(s/2, -s) &= \pi(s, -s) = \pi(s, -s/2) = \pi(s/2, -s/2) = \pi^P_{+-}
\end{align*}
\]

It is immediate to show (see the Appendix) that the first order conditions for the optimal rule in states \((s/2, s), (s, s), (s/2, s/2)\) cannot be satisfied by the same inflation rate. Thus ”pooling” cannot be optimal.\(^{15}\)

\(^{15}\)By computing the expected utility under the pooling \( \pi^P \) rule one finds that

\[
\begin{align*}
U(\pi^P(e, e^0)) &= \frac{4.5}{32} s^2 = 0.141 s^2 \\
E(\pi^P(.)) &= 0, \quad \sigma_{\pi^P}^2 = \frac{9}{32}s^2 = 0.281s^2
\end{align*}
\]

(16)

The pooling rule is clearly preferable to the cheating outcome, (confront (16) and (11)), but it is worse than the optimal rule (confront (16) and (15)).
5 Extensions

Next we discuss some possible extensions of the model. First we consider the case where small and large shocks occur with different probabilities. Second, we briefly discuss the case of many countries.

5.1 Distribution of Shocks

Suppose that ”large” and ”small” shocks occur with different probabilities. How does this affect the results? Two important things happen. First, when the probability associated to either small or large shocks tends to zero, the full information solution applies: the CCB can safely ignore the reports concerning states that occur with zero probability. Second, when large shocks becomes sufficiently likely, the relative inefficiency of the rule of thumb (pooling) becomes negligible.

Assume that the probabilities satisfy

\begin{align}
p(s) &= p(-s) = p/2 \quad (17) \\
p(s/2) &= p(-s/2) = (1 - p)/2
\end{align}

with $0 \leq p \leq 1$, so that large shocks are relatively rare when $p < 1/2$.

5.1.1 Back to Full Information

Consider the ”extreme” cases when $p \to 0$ or $p \to 1$ : here the problem of asymmetry of information disappears. It is easy to show that when large shocks almost ”never” occur, $p \to 0$, the CCB can safely disregard ”large reports” and optimally chooses $\pi^S(s, s/2) = \pi^E(s/2, s/2)$, $\pi^S(-s, s/2) = \pi^E(-s/2, s/2)^{16}$. Similarly, if $p \to 1$, so that small shocks ”never” occur, the CCB can safely disregard ”small reports” and optimally chooses $\pi^S(s, s/2) = \pi^E(s, s)$.\footnote{In the (zero probability) event of two large reports, for example $(s, s)$, any inflation rate (and among them $\pi^E(s)$) will do.}

16
5.1.2 The Inefficiency of the Rule of Thumb

It is easy to show that the "pooling" rule for the general case of distribution (17) is given by

\[ \pi^P_+ = -\frac{s(1 + p)}{2}, \pi^P_- = 0. \]  \hspace{1cm} (18)

Clearly, the higher the probability of large shocks the higher (in absolute value) inflation under pooling. When \( p = 1/2 \), the solution is \( \pi^P_+ = -(3/4)s \), as before. It is very difficult to find a closed form solution for the optimal policy \( \pi^S \) for the case \( p \in (0, 1) \). However, we can resort to a numerical solution (see Table 1 below) and calculate the levels of welfare associated to the optimal rule and the rule of thumb, for different values of the probability of large shocks, \( p \)\(^{17} \):

**INSERT TABLE 1 HERE**

In the extreme cases of only small (\( p = 0 \)) or large (\( p = 1 \)) shocks, the two policies are equivalent (we are effectively in the case of full information). If large and small shocks are equally likely, \( p = 1/2, (p(e) = 1/4, all e) \) we are back to our discrete uniform distribution, with the pooling \( \pi^P \) rule being outperformed by the optimal rule, \( \pi^S \). Interestingly, the relative loss from adopting the rule of thumb first rises and then falls with the probability of large shock, \( p \). The reason is as follows. The two policies attain the full information outcome at the extremes, \( p = 0, p = 1 \): however, welfare is increasing and concave in \( p \) under \( \pi^S \), while it is increasing and convex under pooling, so that their ratio initially rises and then falls with \( p \).

\(^{17}\)In the Appendix we show that part i) of Proposition 1 goes through in non uniform case \( p(e) \), i.e. the rule must over-react to large asymmetric shock. Similarly, the result that symmetric reports \((\tilde{e}, -\tilde{e})\) are not distorted still applies. Finally, a sufficient condition for the rule to under-react to asymmetric shocks of different magnitude (cf part ii of the proposition), is that the probability of large shocks \( p \geq 1/2 \). For the remaining cases (cf part iii of Proposition 1) the optimal policy distorts inflation towards the extremes or the middle depending on whether \( p \) > or < 1/2, respectively.
5.2 Many Countries

Having many countries in the Currency Area aggravates the distortions of asymmetric information. The standard inefficiency one-policy-fits all increases with the number of members, and so does the incentives to misreport information: hence larger distortions in the policy rule are required to prevent mimicking. In order to sketch the argument, let the CCA be formed by \( j = 1, 2, \ldots N \geq 2 \) identical countries, experiencing independent, discrete-uniformly distributed shocks \( e_j \). The full information rule now is

\[
\pi^E(e) \equiv \pi^E(e_1, \ldots, e_N) = -\frac{1}{N} \sum_{j=1}^{N} e_j. \tag{19}
\]

so that inflation has mean zero, and its variance \( \sigma^2 \pi = \sigma^2 e / N \) tends to zero as \( N \) goes to infinity. This implies, from the Central Limit Theorem, that the CCB will ”always” choose an inflation rate equal to zero. It is easy to see that the incentive to exaggerate the shock rises with \( N \). Proceeding as in Section 4.1\textsuperscript{18}, the optimal report of country \( i \) is now \( \tilde{e}_i = Ne_i \).

The larger the number of member countries, the larger the incentive to over-emphasize the shock. As \( N \) grows sufficiently large, it must become increasingly costly to separate the types. Hence the distortions associated with asymmetric information are likely to be fostered by the number of CCA members.

6 Discussion

When members of a currency union experience idiosyncratic shocks, a conflict of interest over the stance of monetary policy arises. If governments have an informational advantage over the state of their domestic economy, this lead to a problem of adverse selection. National

\textsuperscript{18}Under asymmetric information, the indirect utility of country \( i \) under the rule (19) is

\[
W(\pi^E, e_i) = -\frac{1}{2N^2} (\tilde{e}_i^2 + (\sum_{j \neq i} \tilde{e}_j)^2 + 2\tilde{e}_i \sum_{j \neq i} \tilde{e}_j) + \frac{e_i \tilde{e}_i}{N} + \frac{e_i \sum_{j \neq i} \tilde{e}_j}{N}
\]

Taking the expectation and solving for the optimal report, as in Sect.4.1, yields the expression in the text.
authorities exaggerate their shocks in order to shape the common policy towards their needs. Ignoring the problem can be extremely costly, since the monetary authority ends up inappropriately implementing "stop and go" policies that are detrimental to welfare. The paper shows that monetary policy must over-react to large symmetric shocks and under-react to asymmetric shocks of different size. In order to provide the incentives for truthful revelation, monetary policy becomes unduly expansive when all members are in serious depressions and unduly restrictive when they all experience booms; conversely, it reacts too little to economic conditions when some face mild expansions (contractions) and some are in depression (boom). Overall, asymmetric information aggravates the problem of tailoring the policy response to the state of the union’s economy, and causes a welfare loss, that is increasing in the number of member countries. We also show that disregarding some of the information reported by national authorities and adopting a "rule of thumb" is never efficient, although a rule of thumb closely mimics the optimal rule when large shocks are either very rare or very frequent.

How robust are these conclusions? The model is clearly very stylized, yet we think that the conclusions are quite general: for example, the model can be given micro-foundations (see the appendix). An interesting question for future research is whether intertemporal considerations may help to reduce the distortions required for incentive compatibility. Along the lines of Atkenson and Lucas ([1]), one may conjecture that the CCB may induce truth-telling by conditioning her policy not only on current reports, but also on past ones, so that, for example, high inflation in a bad state today may come at the expense of a lower inflation in a bad state tomorrow. The resulting dynamics of inflation over time is a topic worth investigating.

References


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[18] Lockwood, Ben, (1996), "Inter-regional insurance with asymmetric information (mimeo)

7 Appendix

7.1 Microfoundations

Here we provide a theoretical underpinning for the choice of our welfare function. Consider the following model. The world consists of two countries. Each country (domestic and foreign) is populated by a representative infinitely lived agent. We abstract from labor mobility. Both economies are endowed with one homogeneous good, \( e_t \), which is defined in terms of random (i.i.d.) deviations from the trend \( \tau = 0 \) Each period, consumers face a given sequence of prices, tax rates and public spending, \( \{p_t, g_t, \tau_t\} \), observe the realization of their endowment, and decide how much to consume, \( c_t \), and save out of their disposable income. The endowment is taxed at a proportional rate, \( \tau_t \). Households save by carrying nominal money balances, \( M_{t+1} \) into next period. There is neither capital nor bonds in the economy. Preferences are described by an additively separable utility function, where separability is assumed both with respect to time and with respect to the arguments. Consumers choose the sequence \( \{c_t, M_{t+1}\}_{t=0}^{\infty} \) so as to maximize the present discounted value of their utility stream\(^\text{19}\):

\[
\sum_{t=0}^{\infty} \beta^t U(c_t, \frac{M_{t+1}}{p_t}, g_t) = \sum_{t=0}^{\infty} \beta^t \left( u(c_t) + V\left( \frac{M_{t+1}}{p_t} \right) + H(g_t) \right)
\]

(20)

where \( 0 < \beta < 1 \) denotes the rate of time preference, \( \frac{M_{t+1}}{p_t} \) is the stock of domestic money balances at the beginning of period \( t + 1 \), expressed in units of time \( t \) goods, \( V \) and \( H \) are quasi-concave functions. Great simplification is obtained by assuming that utility is linear in consumption, \( u(c_t) = c_t \) (cf. Calvo and Guidotti (1993)[8]). The consumer’s budget constraint under Monetary Independence (MI) is

\[
c_t + \frac{M_{t+1}}{p_t} = (1 - \tau_t)e_t + \frac{M_t}{p_t}
\]

(21)

Similarly, in a CCA, the constraint reads

\[
c_t + \sigma \frac{M_{t+1}}{p_t} = (1 - \tau_t)e_t + \sigma \frac{M_t}{p_t}
\]

(22)

\(^{19}\)Since we need to justify why individuals hold real money balances, we need a model of intertemporal choice. An alternative approach would be to assume that money economizes on transaction costs. In this case real balances enter the budget constraint rather than the utility function. Under certain regularity conditions the two approaches are equivalent. See Feenstra (1986).
where $\tilde{M}_t = M_t + M^*_t$ represents the common currency, which is held by both domestic and foreign households\(^{20}\), and $\sigma = 1 - \sigma^*$ represent the share of the common currency that is held by domestic consumers. For simplicity we assume that $e_t$ is a zero mean i.i.d. disturbance. Depending on the exchange rate regime, the national Central Bank (or the CCB) chooses the sequence of nominal balances, $\{M_t\}_{1}^{\infty}$ (or $\{\tilde{M}_t\}_{1}^{\infty}$) given an initial value $M_0$ ($\tilde{M}_0$).

7.1.1 Government budget constraint

National governments raise revenue by taxing the endowment at proportional rate $\tau_t$ and by seigniorage. For the sake of simplicity we do not consider the choice of $\tau_t$ which is assumed mandatory fixed and constant over time. Again, the budget constraint differs between monetary regimes. Under MI we have

$$g_t = \tau e_t + \frac{M_{t+1} - M_t}{p_t}$$

In turn, in a CCA, the constraint reads:

$$g_t = \tau e_t + \sigma \left( \frac{\tilde{M}_{t+1} - \tilde{M}_t}{p_t} \right)$$

By substituting the government constraint into the consumer constraint for MI and CCA respectively, one finds the resource constraint $c_t + g_t = e_t$

7.1.2 Solution

Solving the private sector maximization problem for the case of MI (20) subject to the constraint (21), and re-arranging the first order conditions for $c_t$ and $M_{t+1}$, recalling linearity, yields

$$1 = V'(\frac{M_{t+1}}{p_t}) + \beta \frac{p_t}{p_{t+1}}$$

This is a standard arbitrage condition that assures that no gains can be made by re-allocating consumption over time. Finally, we place the following restriction on the choice of the optimal

\(^{20}\)Here we are assuming that the sequence of prices in the two countries is the same when they share the same currency.
monetary policy. We assume that the Central Bank chooses the rate of money growth in order to achieve a rate of inflation that is a time-invariant function of the disturbance(s), so that \( \tilde{\pi}_t = \frac{p_t+1-p_t}{p_t} = \tilde{\pi}(e_t) \). It is easy to see that this restriction implies that the rate of money growth, \( \mu_t = \frac{M_{t+1}-M_t}{M_t} \) is also a time-invariant function of the disturbance(s) and equals \( \tilde{\pi}(.) \). Thus we can write the demand for money and consumption in MI as follows:

\[
\frac{M_{t+1}}{p_t} = M(\pi(e_t)), \text{ all } t, \quad M_\pi < 0 \tag{25}
\]

\[
c_t = (1-\tau)e_t - \pi(e_t)M(\pi(e_t)) \tag{26}
\]

where it is convenient to define \( \pi(.) = \frac{p_t+1-p_t}{p_t+1} = \frac{\tilde{\pi}(.)}{1+\tilde{\pi}(.)} \). The same conditions apply in a CCA, with \( \sigma \tilde{M} \) replacing \( M \), and assuming that policy rule is a time-invariant function of both disturbances, \( e, e^* \). These expressions immediately yield the indirect utility function \( W \) in MI

\[
(1-\beta)W(\pi(.), e) = (1-\tau)e - \pi(.)M(\pi(.)) + V(M(\pi(.)) + H[\tau e + \pi(.)M(\pi(\.))] \tag{27}
\]

and similarly for the CCA. The welfare function shows the nature of the optimal seigniorage problem of this economy. The inflation tax finances the provision of public goods, which are valued by consumers. Inflation, however, reduces real money holdings and induces distortions in the demand for money. It is immediate to show that this welfare function, under intuitive conditions, satisfies the assumptions in equation (1)

### 7.2 Proof of Proposition 1

Setting \( p(e) = 1/4 \) in Problem 1 gives the following first order conditions:

\[\text{21From the first-order condition for real balances one can see that a constant rate of inflation implies constant money demand } M_{t+1}/p_t. \text{ But since } \frac{M_{t+1}}{p_t} = \frac{M_{t+1}p_{t+1}}{p_t}, \text{ constant inflation and money demand require that } \frac{M_{t+1}}{p_{t+1}} \text{ is also constant. Thus in equilibrium the rate of money growth must equal the inflation rate.}\]

\[\text{22With a slight abuse of terminology, from now on we will call } \pi, \text{ rather than } \tilde{\pi}, \text{ the inflation rate. Also, given the stationarity of the policy rule, although not of the inflation rate, we suppress the time notation when it is not necessary.}\]
π_{s-s} : W_{π_{-s,-s}}(-s, π(-s, -s)) = λW_{π_{-s,-s}}(-s/2, π(-s, -s)) \tag{28}

π_{s,-s/2} : [W_{π_{-s,-s/2}}(-s, π(-s, -s/2)) + W_{π_{-s,-s/2}}(-s/2, π(-s, -s/2))] = λ[W_{π_{-s,-s/2}}(-s/2, π(-s, -s/2)) − W_{π_{-s,-s/2}}(-s/2, π(-s, -s/2)) - λW_{π_{-s,-s/2}}(-s/2, π(-s, -s/2)) - W_{π_{-s,-s/2}}(-s/2, π(-s, -s/2)] \tag{29}

π_{s,s} : [W_{π_{-s,s}}(-s, π(-s, s)) + W_{π_{-s,s}}(s, π(-s, s))] = λ[W_{π_{-s,s}}(s/2, π(-s, s)) + W_{π_{-s,s}}(-s/2, π(-s, s))] \tag{30}

π_{s/2-s/2} : W_{π_{-s/2,-s/2}}(-s/2, π(-s/2, -s/2)) (1 + λ) = 0 \tag{31}

π_{s/2,s/2} : [W_{π_{-s/2,s/2}}(-s/2, π(-s/2, s/2)) + W_{π_{-s/2,s/2}}(s/2, π(-s/2, s/2))] (1 + λ) \tag{32}

π_{s/2,s} : [W_{π_{-s/2,s}}(-s/2, π(-s/2, s)) + W_{π_{-s/2,s}}(s, π(-s/2, s))] = λ[W_{π_{-s/2,s}}(s/2, π(-s/2, s)) − W_{π_{-s/2,s}}(-s/2, π(-s/2, s))] \tag{33}

where we have exploited the fact that the multipliers of the two incentive compatibility constraints are equal by symmetry: \(λ^+ = λ^- = λ\).

Since the r.h.s. of (29) is zero, \(π_{-s, -s/2}\) is not distorted and coincides with \(π^E_{-s, -s/2}\). Also, from (34) we see that \(π_{-s, s/2} = 0 = π^E_{s/2, s/2}\). But then the r.h.s. of (31) is also zero, implying \(π_{-s, s} = 0 = π^E_{-s, s}\). Thus we are left with equations (28) and (35). These, and the incentive constraint (14) can be written for our quadratic specification as follows:

\[
(π(-s, -s), -s) − λ(π(-s, -s), -s/2) = 0
\]

\[
4π(-s/2, s) + s − 2λs = 0
\]

\[
s^2/8 + sπ(-s/2, s) + \frac{π(-s, -s)}{2} = (s/2)π(-s, -s) = 0
\]

The solution gives \(π^S_{-s, -s} = 1.09s > s, π^S_{-s/2, s} = -0.174s > -s/4; λ^S = 0.152\).

Next we show that a pooling rule that sets \(π_{-s/2, -s} = π(-s, s) = π_{-s/2, -s/2} = π^P\) cannot satisfy the first order conditions above. Suppose that \(π^P\) satisfies optimality condition for state \((-s/2, -s/2)\), equation (33) But then equation (28) would imply that also \(W_{π_{-s,-s}}(-s, π^P_{-s}) = 0\), which is not possible since it violates the assumption that \(W_{π_e}(π, e) < 0\) all \(π\) and \(e\).
7.2.1 Distribution of Shocks

Proposition 1 is modified as follows.

Proposition 2 Let \( \pi^S(\tilde{e}, \tilde{e}') \) denote the inflation rule that solves Problem 1. When the distribution of states of nature is given by (17) and \( 0 < p < 1 \), this policy satisfies the following properties: i) \( \pi^S(.) \) over-reacts to large symmetric shocks (in the sense of Proposition 1); ii) a sufficient (but not necessary) condition for \( \pi^S(\tilde{e}, \tilde{e}') \) to under-react to small asymmetric shocks (as in Proposition 1) is \( p \geq 1/2 \); iii) the rule coincides with \( \pi^E(.) \) in the cases \( \pm(s/2, s/2), (s/2, -s/2) \); iv) for the cases \( \pm(s, s/2) \) there are multiple solutions. When \( p < 1/2 \), the policy associated to a global maximum distorts inflation towards the extremes \( (\pi^S(-s, -s/2) > \pi^E(-s, -s/2) = 3/4s, \pi^S(s, s/2) < \pi^E(s, s/2) = -3/4s) \); when \( p > 1/2 \) the distortion is towards the center: \( \pi^S(-s, -s/2) < \pi^E(-s, -s/2), \pi^S(s, s/2) > \pi^E(s, s/2) \); finally when \( p = 1/2 \), the policy rule \( \pi^S \) is not distorted, as in Proposition 1.

Proof. When the probability distribution of shocks is given by (17), the first-order conditions become:

\[
\begin{align*}
\pi_{-s,-s} & : p W_{\pi(-s,-s)}(-s, \pi(-s,-s)) = \\
& \lambda (1-p) W_{\pi(-s,-s)}(-s/2, \pi(-s,-s)) \\
\pi_{-s,-s/2} & : p (1-p) W_{\pi(-s,-s/2)}(-s, \pi(-s,-s/2)) = \\
& -p (1-p) W_{\pi(-s,-s/2)}(-s/2, \pi(-s,-s/2)) \\
\pi_{-s,s} & : p \left[ W_{\pi(-s,s)}(-s, \pi(-s,s)) + W_{\pi(-s,s)}(s, \pi(-s,s)) \right] = \\
& \lambda W_{\pi(-s,s)}(s/2, \pi(-s,s))(1-p) \\
& \lambda W_{\pi(-s,s)}(-s/2, \pi(-s,s))(1-p) \\
\pi_{-s/2,-s/2} & : \left( \frac{1-p}{2} \right)^2 W_{\pi(-s/2,-s/2)}(-s/2, \pi(-s/2,-s/2)) (1+\lambda) = 0 \\
\pi_{-s/2,s/2} & : \left[ W_{\pi(-s/2,s/2)}(-s/2, \pi(-s/2,s/2)) + W_{\pi(-s/2,s/2)}(s/2, \pi(-s/2,s/2)) \right] \left( \frac{1-p}{2} \right)^2 (1+\lambda) = 0 \\
\pi_{-s/2,s} & : \frac{(1-p)p}{2} \left[ W_{\pi(-s/2,s)}(-s/2, \pi(-s/2,s)) + W_{\pi(-s/2,s)}(s, \pi(-s/2,s)) \right] = \\
& \lambda \left[ \left( \frac{1-p}{2} \right)^2 W_{\pi(-s/2,s)}(s/2, \pi(-s/2,s)) \right] - \\
& \left( \frac{1-p}{2} \right) \left( \frac{1-p}{2} \right) W_{\pi(-s/2,s)}(-s/2, \pi(-s/2,s)) 
\end{align*}
\]
Comparing (37) with (28) we can see that the condition for \( \pi(-s,-s) \) is unaffected by the change in the distribution. A similar condition holds for \( \pi(s,s) \), so that part i) of Proposition 2 holds.

Comparing (39) with (29) we can see that when \( p = 1/2 \), \( \pi(-s,-s/2) \) is not distorted, while if \( p > 1/2 \), the r.h.s. of (39) is positive, since \( W_{\pi(-s,-s/2)}(-s/2,\pi) < 0 \), so that \( \pi(-s,-s/2) \) is below the full information value, see part iv) of Proposition 2.

Finally, comparing (45) with (34) we see that \( \pi(-s/2,s/2) \) is the same as in full information. This and equation (44) implies that also \( \pi(-s,s) \) from (41) is the same as under full information, cf point iii).

The case for small asymmetric shocks, \((-s/2,s)\) is slightly more complex, since there are multiple solutions. Computing these solutions numerically and taking the one that delivers global maximum gives a value of \( \pi(-s/2,s) < s/2 \) (which is reasonable since the \( \pi(-s/2) = s/2 \)). When this inequality is satisfied, we see that the r.h.s. of (46) \( \left( \frac{2p-1}{2} \right) \pi - \frac{s}{4} \) is surely negative for \( p \geq 1/2 \). Thus, under this condition, the l.h.s. of (46) is also negative, implying that \( \pi^A(-s/2,s) > \pi^E(-s/2,s) \), cf part ii) of Proposition 2.
\[
U(\pi) / p \quad 0 \quad 1/8 \quad 1/4 \quad 1/2 \quad 3/4 \quad 7/8 \quad 1
\]

| \(U(\pi^S)\)   | 0.062s^2 | 0.085s^2 | 0.108s^2 | 0.15502s^2 | 0.2022s^2 | 0.226s^2 | 0.25s^2 |
| \(U(\pi^P)\)   | 0.062s^2 | 0.079s^2 | 0.098s^2 | 0.141s^2   | 0.192s^2  | 0.219s^2 | 0.25s^2 |

\[
U(\pi^S)/U(\pi^P) - 1 \quad 0 \quad 7.6\% \quad 10.8\% \quad 10.2\% \quad 5\% \quad 3.2\% \quad 0
\]

Table 1: Numerical solutions for Welfare under the Optimal Rule, \(U(\pi^S)\) and the Rule of Thumb, \(U(\pi^P)\).
Figure 1: The Separating Rule