THE IMPACT OF INCREASING TRANSPARENCY IN MONETARY POLICY ON INFLATION AND UNEMPLOYMENT

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Abstract

The increasing transparency of central banks’ internal communication and decision-making methods has been a global trend in the past fifteen years. Especially since the financial crisis in 2008, the general public has demanded greater transparency from governments and major market participants. This paper examines how the increase in information about the conduct and expectations of central banks affects unemployment rates and price level changes, especially in the context of a society in which there is a significant union presence. It finds that greater transparency fails to improve welfare when public information is released in such a way that agents place too little weight on their own information and when there is an uncoordinated-wage-decision externality among unions.
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1 Introduction

As central banks around the world continue to increase the amount of information they make available to the public, we want examine the assumption that greater transparency leads to both greater effectiveness of monetary policy, and to more socially beneficial outcomes. With a closer examination into what information central banks release and how that information is perceived by the public, a greater understanding of the effectiveness of monetary policy can be achieved.

To do this, we examine two models. The first, by James and Lawler (2010), examines how information released by the central bank affects an economy characterized by monopolistic competition and homogeneous private information. The second, from a paper by Angeletos and La’O (2009), looks at how public information affects an economy with perfect competition between firms and decision-making made based on heterogeneous information.

This paper is structured as follows. Section 2 gives an overview of the historical development of monetary policy in central banking. Section 3 talks about the various methods central banks have of increasing their transparency, and how the availability of information affects higher-order beliefs, section 4 presents an attempt by James and Lawler (2010) to model the effects of transparency when wage-setters have access only to homogeneous information, and section 5 is a formalized extension of this model, in which the wage-setters act under heterogeneous information. Section 6 concludes.

2 Development of Central Banking Policy

Until the 1990s, conventional wisdom held that those in charge of monetary policy should say as little as possible about their motives and future policy decisions (Blinder et al., 2008). Today, the mainstream opinion of those involved in central banking is the exact opposite. Monetary policy is now seen as the art of managing the expectations of the public, with the financial instruments directly controlled by central banks, such as overnight interest rates, considered less important than the information the bank sends out (Morris & Shin, 2008). How the central bank’s messages affect markets and individuals is of particular concern.

A movement towards greater transparency continues in the hopes that allowing the public to access more information about central banks’ motives and actions will have positive outcomes for both social welfare and for allowing monetary policy to have its intended effects on financial markets (Blinder et al. 2008, James & Lawler 2010). But what do we mean, exactly, by the term "transparency?" One interpretation is that it is a metaphor for any feature of the central bank which influences the private sector’s expectations about future monetary policy,
and hence future economic development (Jensen, 2002). Transparency can also be thought of as the degree of accuracy of the signals the central bank releases. When the signals become more accurate in regards to the exact nature of an economic shock, we say that the bank has become more transparent (James & Lawler, 2010).

### 2.1 Historical Background

The persistent problem of "stagflation" in the 1960s and 1970s led to increased interest in regards to if, and how, monetary policy could stabilize prices while reducing unemployment. The degree of discretion a central bank should be permitted to exercise was of interest as well. When a central bank is operating under complete discretion, it is free at any time to alter its policy settings.

In 1985, Kenneth Rogoff proposed that, under certain circumstances, society can make itself better off by appointing a "conservative" central banker to handle monetary policy. The conservative agent’s objective function would be different than society’s objective function and would place "too large" an emphasis on stabilizing the price level compared to stabilizing unemployment. The central banker would, however, be able to change the weights given to unemployment and price level stabilization depending on the current state of the economy. The greater emphasis on price level stability would reduce the time-consistent rate of inflation, but would increase the variance of employment during realizations of large supply shocks (Rogoff, 1985). This idea of "intermediate monetary targeting" was a departure from the traditional idea that the central bank needs to rigidly adhere to a strict feedback rule, which Rogoff advised central banks to do only under very special circumstances.

The theory behind appointing a conservative central banker has since gone out of favor. Rogoff only considered an economy with an atomistic labor market, in which wage-setting agents have no market power. Lawler (2000) showed that, in an economy where wages are set by a single union representing all workers, it is optimal for the central bank to care only about employment. Skott (1997) found that when there are labor unions in the economy, a central bank that is totally indifferent to the level of inflation may obtain outcomes with zero inflation and high unemployment, while inflation-averse banks may end up with high inflation and low unemployment. As the true state of the labor market lies somewhere in-between being completely atomistic and represented by a single union, there is still debate as to how exactly the central bank should conduct monetary policy.

#### 2.1.1 Time Inconsistency Problem

In addition to finding ways to combat stagflation, there was the issue of trying to find an optimal monetary policy that was time consistent. A policy is *time
consistent if some action planned at time period \( t \) for time period \( t + 1 \) is still optimal to implement when time period \( t + 1 \) actually arrives (Walsh, 2003). A time-consistent policy can, of course, depend on the realization of events which are unknown when the policy is designed. Then, in order to be time-consistent, the planned response to new information must remain the optimal policy when the new information arrives.

The undesirability of time-inconsistent policies is related to the credibility of central banks and their communication with the public. If the central bank conducts monetary policy according to a systematic rule, and if this rule is publicly available, theoretically the public could predict the bank’s optimal behavior for its objective function. Market participants would then adjust their investment and spending patterns to account for the bank’s future actions. These adjustments lead to more efficient market outcomes, but only if the central bank commits to its future policies, i.e. acts in a time-consistent manner.

In many dynamic problems, economic performance can be improved by changing the policy in the future from what is announced in the present (Taylor, 1983). Unless the central bank has a way to credibly precommit to policies, or is required to adhere to certain policies, it will try to make changes when new information or situations arise, especially when private agents have precommitted to wage and price decisions. If private agents believe that the central bank is not committed to its current monetary policy, the agents will include the possibility of policy changes into their nominal prices and wages, so that adjustments to monetary policy will not affect real macroeconomic variables. In the 1970’s, several influential papers were published stating that it would be difficult, if not impossible, for a central bank to conduct monetary policy in a way that is both optimal and time-consistent.

Kydland and Prescott’s seminal paper found that, under discretionary monetary policy and rational expectations, the social objective function will not typically be maximized (Kydland & Prescott, 1977). They point out that the decisions of economic agents depend not only on current and past decisions, but on their expectations of future actions. These expectations change as current plans change, so if, in each period, the selected policy is the one which maximizes the sum of the value of current outcomes and the discounted valuation of the end-of-period state, the selected policy will be time consistent but not optimal. This paper drew more attention to the issues surrounding the central bank’s ability to believably precommit to policies (Walsh, 2003).

Calvo (1978) examined the time consistency of Ramsey-Friedman optimal policy, in which one maximizes a sum of instantaneous utilities that depends on consumption and real monetary balances. He found that the optimal monetary policy will be time-inconsistent even when the government tries to maximize the welfare of the representative household. This is because the amount of real mon-
etary balances that people are willing to hold in the current time period depends on the rate of inflation between the current and subsequent time periods. If private agents owe the government even a small amount, then the government has an incentive to decrease the price level, so that the nominal value of these debts increase. However, if the government were to do this often, they would face a severe credibility issue and the costs from this price level manipulation would probably be greater than the gains from increasing the value of their loans.

Despite these grim predictions as to the impossibility of finding a time-consistent and socially-optimal monetary policy, in the past decade it has been shown that, under certain conditions, it is theoretically possible for such a policy to exist.

Alvarez et. al (2004) show that optimal policies will be time consistent for a class of monetary economies commonly used in applied work. These economies do not include any capital and the policy chosen by the government in the first period ends up being the policy used by all successor governments. This monetary policy is known as the Friedman rule and sets the nominal interest rate equal to zero and is the optimal policy under commitment. By carefully constructing the government’s maturity structure of nominal and real debt, successor governments will not be tempted to change the price level in order to inflate or deflate their nominal claims. There are two main ideas behind these findings. Firstly, the government’s primary influence over successor governments comes from the appropriate setting of real debt as opposed to nominal debt. Secondly, when the Friedman rule is not optimal, the government does not have enough free debt instruments to coerce its successor into continuing the present government’s plan.

In a slightly different situation, Calvo and Obstfeld show that, when the government has an infinite planning horizon, it is possible for the social planner’s optimal allocation to be time consistent. Other requirements for time consistency in their model include the ability of the government to distinguish between different groups of people when making lump-sum transfers and the availability of sufficient policy tools available to the planner.

2.2 Central Bank Independence

Though constructing a socially-optimal and time consistent monetary policy is theoretically possible, it is clear that implementing such a policy in real life would be extremely difficult. The idea that central banks would be tempted to change their publicly-announced policies for immediate gain and thus lose their credibility with the public brings us to the debate about the amount of control governments should have over monetary policy.

The departure of the central bank’s short-term goals from those of the wage-setters is a main reason for many central banks’ relatively large degree of autonomy today. If the central bank could be easily pressured by unions or various interest
groups into giving more weight to reducing unemployment variability, then the central bank’s response to variations in employment and inflation would be optimal for certain subgroups of the population, but may not be the best policy for society as a whole. However, it is not beneficial for the central bank to focus solely on reducing inflation. All major central banks include improving the well-being of society as a main (or ultimate) reason for their existence and doing so involves stabilizing the unemployment rate to some extent. Another reason for granting central banks some level of independence is that, during the last two decades, both theoretical and empirical research has shown that central bank independence is associated with lower inflation while not being associated with lower growth (Cukierman, 2001).

In addition to affecting domestic macroeconomic variables, the issue of central bank independence is increasingly important in international financial and monetary cooperation (Maxfield, 1994). In order to maintain stable exchange rates, monetary authorities in different governments need to be able to coordinate different monetary policies. For the coordination efforts of the central bank to appear credible, there needs to be a guarantee of central banks’ monetary authority and independence from their national governments.

A central bank has goal independence when it is free to conduct monetary policy as it wishes. Its government may require the central bank to reach certain targets, and impose penalties for not reaching those targets. When this happens, the central bank does not have goal independence, only instrument independence (Herrendorf & Lockwood, 1997). Governments usually give a clearly defined mandate to central banks, which can be quantitative or qualitative.

Even if a central bank is not given a specific numerical target, it may announce that it will try and reach a certain target of its own quantification (Blinder et al., 2008). Quantitative targeting allows the central bank and others to assess the central bank’s ability in reaching its desired goals, and helps anchor the expectations of the public. Well-anchored inflation expectations help stabilize actual inflation by removing a major source of shocks, making it easier for a central bank to affect real inflation just by credibly stating it wants to keep inflation at a certain level.

### 2.3 Commitment Versus Discretion

Unsurprisingly, there disagreement among academics and policy makers as to whether economic outcomes are better when central banks commit to following certain policy rules, or if they should change their policies as the economic climate changes. One extreme would be for the policy maker to constantly be adjusting all of the variables under the central bank’s control to any value she wished in order to reach her short-term goals, which may change frequently. The other extreme is that the central bank strictly complies with a stated policy rule,
whether that be mandated or voluntary, and does not change these rules or goals over long periods of time. The central bank is said to have discretion if it varies its policies with changes in its private information, and conventional wisdom is that optimal outcomes can be achieved only if the monetary authority is given some level of discretion (Athey et al., 2005).

As many central banks today are at least some degree separate from their governments, the issue of how much discretion they should use when economic shocks arise is of increasing interest. There is a tradeoff between maintaining the credibility needed to keep inflation low and the flexibility necessary to conduct stabilizing monetary policy (Cukierman, 2001).

Athey, Atkeson and Kehoe (2005) showed that the optimal degree of discretion depends on the severity of the time inconsistency problem and the usefulness of private information in the examined society. With a severe time inconsistency problem and little useful private information, it is optimal to allow the central bank no discretion. The government can ensure the optimal monetary policy is implemented by enforcing a simple inflation cap, which would vary with developments in publicly available information.

However, a discretionary regime can be more flexible. The real-time aspect of choosing whether to operate under commitment or discretion means that opting for discretion in the current time period leaves open the possibility of the central bank moving to a commitment regime in the future (Haubrich & Ritter, 2000). The value of having the option to wait increases as uncertainty increases. However, if the central bank waits too long to decide how to conduct policy, their credibility, and therefore policy effectiveness, may suffer.

2.4 Effectiveness of Monetary Policy

Of course, any discussion about which economic aggregates a central bank should spend its efforts stabilizing is pointless if the central bank’s monetary changes have no effect on the economy. New classical economists maintain that if the private sector rationally anticipates the central bank’s policies, monetary policy cannot affect real behavior. The reasoning is that, in order for monetary policy to induce changes in real output, it has to be able to cause unexpected movements in the price level (Sargent & Wallace, 1975). From the assumption that expectations of the price level are rational, logic tells us there is no systematic rule the central bank can follow that allows it to affect the price level unexpectedly. Any changes in the money supply will be accounted for by the wages set by the unions. The central bank could add an unpredictable random term to its money supply function, but this would not enable them to establish a systematic countercyclical monetary policy.

Others argue that it seems inconceivable that large and influential unions would
not change their real wage behavior in response to the anticipated effects of monetary policy (Lucas, 1976). If the unions’ expectations are not allowed to change as monetary policy changes, their expectations are no longer rational. The changes in the private sector’s policies would have an effect on unemployment, so it is not unreasonable for the central bank’s behavior to have consequences for both inflation and unemployment. Additionally, the combination of the bargaining structure and the central bank’s policies have been shown to determine the equilibrium level of unemployment, even when all parties have rational expectations and complete information (Iversen, 1998).

A situation in which the private sector has complete information can arise only when there is complete transparency about the behavior and motivations of the central bank and when all parties involved are paying close attention to this information. Until banks increase the amount of information to such an extent that the public is perfectly informed of the bank’s actions and motivations, we can expect that the central banks’ monetary policies will affect the price level and possibly unemployment. It is the ability of the central bank to release information which affects macroeconomic variables that brings us to the issue of increasing central bank transparency.

3 Transparency

The increasing transparency of central banks’ internal communication and decision-making methods has been a global trend in the past fifteen years. Especially since the financial crisis in 2008, the general public has demanded greater transparency from governments and major market participants (Morris & Shin, 2002). There are two main reasons for increasing the transparency of central banks.

The first is the common sentiment that, in a democratic society, the public has the right to know what the central bank is doing and what it wants to achieve. Opaqueness is often associated with secrecy and dishonesty, and so an increase in central bank information could increase the general public’s trust in the financial system (Jensen, 2002). When a central bank is democratically accountable, mechanisms are in place for elected officials to override the central bank’s actions and stated objectives (Cukierman, 2001). If the central bank must answer to the public in some way or face penalties, it will need to explain its actions and motivations. These explanations increase transparency and allow the public to be aware of any actions committed by the central bank that go against the will of the people. Theoretically, greater transparency would lead monetary policies that are of greater social benefit to the majority of society.

As explained earlier, there is also a benefit to having a mostly-independent central bank. However, its members and policies will still be, at some level, de-
terminated by the government, which (hopefully) is elected by the general public. Transparency may compensate somewhat for the "democratic loss" that society incurs from central bank independence (Jensen, 2002).

The second and more commonly stated benefit of increasing transparency is that communicating with the public makes the central bank more predictable to markets. When markets can accurately predict central bank policy, they will respond more efficiently to changes in those policies. They can conduct transactions that maximize economic growth by minimizing the economic loss that comes from expectational errors (Poole, 2001). These expectations lead to private sector inferences about future economic developments and to real movements, especially in forward-looking variables. How investors form their future expectations in reaction to central bank announcements depends greatly on the central bank’s perceived commitment to its policy rules, the nature of the policy announcement, current market conditions, and the amount of information currently available.

Exactly how central bank information affects the public, and to what degree depends greatly on the communication style of the individual bank. Even if two central banks follow the same monetary policy, they may have drastically different communication policies, which can have different effects on financial markets.

3.1 Information Releases

Central banks release information on four major aspects of monetary policy: their overall objectives and strategy, their motives behind a particular policy decision, their opinion on the state of the economy and their predictions of future monetary policy decisions (Blinder et al., 2008). Below we examine the policies of the Federal Reserve System (the Fed), the Bank of England (BoE), and the European Central Bank (ECB). In addition to being three of the world’s major central banks, these banks showcase different communication methods used in monetary policy.

3.1.1 Objectives and Strategy

The ultimate goal of all central banks is to provide a stable means of payment (Schwartz et al., 2009). This is achieved mostly by maintaining the stability of the country’s or region’s currency. In the early days of central banking, achieving high rates of employment and long-term growth were considered to be of equal importance to ensuring price stability. Most central banks now state that price stability, or keeping inflation close to zero percent, is their foremost policy goal. Inflation targeting involves setting the current policy instrument at a level that would make the expected value of inflation equal to the central bank’s inflation target (Cukierman, 2001).
This significant change in policy came from a shift in the idea that there was a long-run trade-off between inflation and unemployment to the belief that there is only a relationship between \textit{unexpected} inflation and employment and output (Schwartz \textit{et al.}, 2009). The latter relationship, called the expectations-augmented Phillips curve, implied that if the central bank had an informational advantage over the private sector, monetary policy could be used to smooth business cycle fluctuations.

Despite the general consensus on the importance of stabilizing the price level, central banks have different objectives mandated by their governing bodies. In the Fed, The Board of Governors and the FOMC are required by the Federal Reserve Act to conduct policy conducive towards achieving the goals of maximum employment, price stability and long-term interest rate stability, without a specified weight given to the different goals. Since the appointment of Paul Volcker in 1979, the Fed has appeared to have put most of its efforts into keeping inflation low but positive. The BoE is required by the Chancellor of the Exchequer to meet a symmetrical inflation target, in which inflation is currently measured by the CPI. The Maastricht Treaty mandates that the primary objective of the ECB is price stability in the eurozone, but gives no numerical targets for price stability or inflation. However, the ECB gives itself an inflation target as a part of its monetary policy strategy. Meeting an established numerical objective gives helps the bank anchor the expectations of market participants and provide accountability.

The Fed does not have an official strategy, but appears to follow a simple "Taylor rule" (Schwartz \textit{et al.}, 2009). If the Federal Funds rate is 1% or more above/below 2% inflation or potential GNP, the Fed Funds rate is adjusted by 0.5 percentage-point steps. The Fed also uses open market operations and sets reserve requirements to change inflation rate.

The BoE follows interest rate targeting, in which it changes the official Bank Rate paid on commercial bank reserves to keep inflation near the rate required by the Chancellor (currently 2%). The BoE also conducts purchases of private assets to increase liquidity and boost nominal demand if the interest rate has fallen too low to be decreased any more (Bank of England, 2012).

The ECB follows a strategy comprised of a quantitative definition of price stability and analyzing the risks to price stability using both economic and monetary analysis (European Central Bank, 2012). The Governing Council of the ECB defines price stability as a year-on-year increase in the Harmonised Index of Consumer Prices (HICP) of less than 2% for the euro area. To affect the price level, the ECB uses open market operations, standing facilities (which provide a floor and ceiling for the overnight market interest rate) and sets the minimum reserve requirements for credit institutions.

Publishing the specifics of what a central bank is required to do makes the
central bank accountable to its governing body, and to the public. If the central bank fails to meet a specific target, they are usually required to present reasons why they did not meet that target and what they will do to improve their policy-making within the next quarter or year. For example, if the BoE fails to keep inflation within 1 percentage point above or below target, it must send an open letter to the Chancellor explaining why inflation has deviated so much and state what the bank will do about it (Schwartz et al., 2009). If these reports are unsatisfactory often enough, presumably there will be negative consequences for the central bankers, which will provide incentives for the central bank to perform to the best of its abilities.

3.1.2 Policy Motives and Opinions

Just as important as what a central bank’s main goal is and the means by which the central banker attempts to accomplish it are the reasons behind the central banker’s policy decisions. The decisions are released in different formats, with differing degrees of detail as to how and why a certain decision was made.

The Federal Reserve’s strategy is quite different from most other central banks, as it keeps its staff projections secret but publishes its FOMC inflation forecasts for the next three years quarterly. The full transcript of the meeting is not published, but votes are attributed to each committee member so that the public is able to see the degree of dissent on a decision. The Chairman of the Board reports to Congress every three months when the Fed releases its forward-looking assessment of future monetary policy. It is interesting to note that before 1994, the FOMC did not publicly announce its target for the federal funds rate after the meeting at which it was determined (Woodford, 2005). Markets could only try and guess what the fed funds rate was by looking at the Fed’s open market operations.

The BoE publishes a report on inflation every quarter, after which it reports to Parliament. It publishes the minutes, but not the full transcript of its Monetary Policy Committee meetings, and also attributes the votes of its members. Additionally, it releases summaries of its Financial Policy Committee meetings, an annual report, a quarterly bulletin, and a biannual report on financial stability.

Between 1993 and 1996, the BoE released charts with a uniformly-shaded range of uncertainty around the bank’s central projection of inflation. This type of chart was abandoned because it encouraged the reader to focus on the central projection, implied the bank’s inflation project was very precise, and gave no weight to the discussion of risks to the forecasts (Britton et al., 1998). The BoE now uses the fan chart which, according to the BoE, is a better tool for showing that "monetary policy is about making decisions in an uncertain world." There are fan charts for predictions of both GDP and the CPI. The following is a chart showing the predicted percentage change in prices from a year earlier:
The ECB publishes annual and weekly reports and a monthly bulletin. It releases its forecasts, but the ECB explicitly says these numbers are projections and not commitments to a certain policy action. It does not publish full transcripts or minutes of its meetings, and does not publish a record of the individual votes in its meetings. Instead of fan charts, the ECB releases staff projections of GDP and HICP forecasts, which are given as an interval of values:

<table>
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<tr>
<th>Table 1</th>
<th>Macroeconomic projections for the euro area</th>
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<tbody>
<tr>
<td></td>
<td>2011</td>
</tr>
<tr>
<td>HICP</td>
<td>2.7</td>
</tr>
<tr>
<td>Real GDP</td>
<td>1.5</td>
</tr>
<tr>
<td>Private consumption</td>
<td>0.2</td>
</tr>
<tr>
<td>Government consumption</td>
<td>-0.3</td>
</tr>
<tr>
<td>Gross fixed capital formation</td>
<td>1.6</td>
</tr>
<tr>
<td>Exports (goods and services)</td>
<td>6.3</td>
</tr>
<tr>
<td>Imports (goods and services)</td>
<td>4.1</td>
</tr>
</tbody>
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1) The projections for real GDP and its components refer to working day-adjusted data. The projections for imports and exports include intra-euro area trade.

For brevity’s sake, the main focus in this paper is on only three central banks.
However, one recent change in central bank policy in several smaller central banks is of significant interest, especially in regards to increasing transparency of monetary policy. The central banks of some countries including Norway, New Zealand, Iceland and Sweden publish not only their estimates of the output gap, but also the numbers underlying their macroeconomic forecasts (Blinder et al., 2008). Svensson (2006) says that announcing the central bank’s optimal projection and the analysis behind the predictions would be the most effective way to implement monetary policy, as this allows the most precise and advanced evaluations of the bank’s monetary policy and decisions.

While people well-versed in central bank behavior welcome the extra information, there is a concern that these predictions will confuse the public, who may not understand the conditional nature of the forecasts (Blinder et al., 2008). The act of releasing these forecasts could also make complicate the banks’ decision making processes. If the difference between a bank’s predictions and the policy the bank ends up using is too large, that discrepancy may damage the central bank’s credibility and induce economic agents to misallocate resources if their decisions were based on the central bank’s forecasts. Since the step forward in transparency is relatively young, more years of data will be needed to see if the increase in information has a significant effect on financial markets and bank credibility.

3.1.3 Timing

As economic statistics are unavoidably imperfect measurements of sometimes imprecise concepts, no central bank can guarantee that the information they release to the public is one-hundred percent accurate. It is for this reason that central banks are concerned that the benefits financial markets gain from knowing what the central banks’ decisions are as soon as possible are outweighed by the disproportionate impact of any error the quickly-released data would have on altering future expectations (Morris & Shin, 2002). A main challenge for central banks is to release information in a timely-enough manner to allow the private sector to pursue its goals but not release it so quickly that errors in the data cause severe problems.

Today, most central banks release their data and opinions to the public on the day they are established. This is a recent and significant change. It was not until 1994 that the Federal Reserve started announcing changes in its target federal funds rate on the day of its Federal Open Market Committee (FOMC) meetings (Blinder et al., 2008). Announcing policy decisions creates news, but making the decisions public immediately eliminates any guessing by market participants, thus increasing the signal-to-noise ratio.

Opinions differ as to what information should be released. The Fed and the Bank of England publish both minutes and information on how each member of the
committee voted in the meeting, while the ECB only publishes a press statement with its policy decision. The minutes undergo an editing process that results in a substantial time delay before the information is made public. The ECB holds press conferences immediately after their meetings about policy decisions, which has the advantage of sending information to market participants as soon as possible. The opportunity for the public to ask questions during these announcement sessions can help clarify any misunderstandings that are in the press release (Blinder et al., 2008).

All major central banks today make decisions by committee. The most natural occasion for communication by a Monetary Policy Committee (MPC) happens on the days of meetings, which are when decisions are announced. The timing and content of communications about meetings differs substantially across central banks. The Fed puts out a short press release containing the policy decision, a short explanation of the motivation behind the decision, and occasionally predictions about the economy in the near future. The Bank of England usually only provides an explanation of its decisions when it does something unexpected or when it changes interest rates. The ECB releases both a press statement that is less detailed than those of the Fed and the Bank of England, and holds a press conference on the day of Governing Council meetings. The ECB does not release minutes of the meetings, while the other two banks do; however, the ECB’s press conference has the advantage of putting out information sooner, as the minutes for the Fed and the Bank of England are not published immediately after MPC meetings.

All of these central banks are legally required to provide an annual report and appear before its legislature. The ECB publishes the *Monthly Bulletin*, which assesses economic development and provides information pertaining to the analytical framework used in its decision-making process. The Bank of England publishes its quarterly *Inflation Report*, which provides a "comprehensive and forward-looking framework for discussion" among its MPC members to facilitate decision making and explain the MCP’s decisions, along with the *Quarterly Bulletin*, which comments on current market events and monetary policy operations. The Fed publishes a semiannual *Monetary Policy Report to the Congress*, which comments on the basic state of the economy and the Fed’s predictions.

### 3.2 Effects of Transparency

Proponents of transparency give both economic and moral reasons for increasing the amount of information available to the public. The ECB states that transparency not only helps the public understand its monetary policy, it is crucial for the credibility, self-discipline and predictibility of the central bank. Additionally, varying degrees of transparency will affect the public’s expectations of inflation and
employment. When a central bank operates with limited transparency it keeps information about shocks private at the time inflationary expectations are informed and put into wage contracts. With full transparency, the information about the shocks is released to the public before expectations are formed (Cukierman, 2001).

Usually, transparency in financial matters is seen as beneficial for the welfare of the general public. There is evidence that when the central bank has private information about its own shifting objectives, greater transparency regarding its objectives leads to higher social welfare (Cukierman, 2001). However, several papers show that the instinct to assume that greater transparency always results in better outcomes for society should be examined in greater detail. Some models of transparency have come to the conclusion that full transparency is not always best for society in every aspect (Jensen, 2002). Though complete transparency may be necessary politically, such a policy may not be optimal from an economic point of view.

James and Lawler’s (2010) model (discussed in Section 5) supports the hypothesis that changing the degree of transparency of the central bank will affect the unemployment rate and the price level, and possibly be detrimental to public welfare. Morris and Shin (2002) argue that when agents have no private, socially valuable information, greater transparency always increases the public’s welfare. When agents also have access to private and independent sources of information, increasing the amount of information available to the public may be harmful in some cases. Jensen (2002) finds that the welfare effects of increased transparency depend on the reputation of the central bank, and the current state of the economy. Greater transparency leads to a more consistent central bank, but this may be detrimental to economic stabilization during shocks. Cukierman (2001) finds that, when central banks have more than one objective, expected social welfare is higher with limited transparency than with full transparency.

3.3 Higher-Order Beliefs

Differing methods of releasing information affect not only the public directly but also decisions made by both the bank and the public in an indirect manner. These indirect effects may be just as important to financial markets and monetary policy effectiveness as are the direct effects. This hypothesis has led to an increased interest in how higher-order beliefs affect central banking. Taking into account what agent A thinks agent B believes, based on agent B’s actions (called agent A higher-order beliefs), agent A may respond differently to new information compared to how agent A would respond if they only considered their own expectations (agent A’s first-order beliefs).

It has been proposed that higher-order beliefs are not as quick to change in response to greater transparency as are first-order beliefs. This delay leads to
temporary real effects of nominal changes in the money supply (Woodford, 2003) (Angeletos & La’O, 2004). Though information on the money supply may be readily available to those who search for it, many people will not know to do so, or will ignore current facts in favor of internalized biases. The value of the current money supply is usually published within a month after it has been established, but the effects of monetary disturbances have been shown to linger for several quarters after the information’s release (Woodford, 2003). Woodford (2001) attributes this lack of adjustment to the inaccuracy of peoples’ subjective perceptions, rather than to errors in the data.

Angeletos and La’O (2009) reason that if not all firms have full information about an economic shock, at the time the shocks occurs, the fully-informed firms will adjust their prices only partly, as other firms with less complete information will not respond to the shock with a full price adjustment. Of course, how much all of these firms’ prices affect one another. The degree of strategic complementarity has a large effect on the adjustment rate of expectations. If decisions by different economic agents are strategic complements, then higher-order expectations will adjust more slowly than if there is a small degree of strategic complementarity (Woodford, 2003).

The importance of higher-order beliefs to central bank communication is related to central bank’s credibility problem and past accuracy in forecasting economic shocks. If the central bank has a history of being extremely good at predicting what will happen in the economy, the private sector will most likely believe that the central bank’s statements about changes in the economic climate and will follow the central bank’s lead in regards to employment contracts and wages. However, if the private sector believes the bank’s belief about the future state of the economy is inaccurate, they will follow their own private research, and monetary policy will not be effective. It becomes difficult very quickly to ascertain the effects of higher-order beliefs, but is worth looking at second-order beliefs at least, especially as both private firms and central banks come up with more extensive reports and forecasts.

4 Modeling the Effects of Transparency with Homogeneous Private Information

The following model was constructed by James and Lawler in order to examine the effects of increasing the transparency of central banks on wage and unemployment levels. They assume that the economy’s output is produced by monopolistically competitive firms that share a Cobb-Douglas production technology. All of the variables (except inflation) are in logarithmic form unless otherwise noted, and all
parameters are constrained to be positive. Labor is the only variable input.

The relationship between firm $i$’s output, $y_i^*$, and employment, $l_i$, is described by

$$y_i^* = \alpha l_i + \theta, \quad 0 < \alpha < 1,$$

(1)

where $\theta \sim N(0,\sigma^2)$. The demand for firm $i$’s output, $y_i$, as a proportion of aggregate demand, $y$, is determined by firm $i$’s price, $p_i$, relative to the aggregate price level, $p$:

$$y_i - y = -\varepsilon(p_i - p)$$

(2)

where

$$y = \int_{i=0}^{1} y_i di, \quad \text{and} \quad p = \int_{i=0}^{1} p_i di$$

The parameter $\varepsilon$ represents the relative price elasticity of product demand and shows the degree of competition within the goods market; under perfect competition we would have $\varepsilon \to \infty$. The parameter $\varepsilon$ measures the elasticity of substitution between goods. Aggregate demand is determined by the real money stock, or the nominal money supply, $m$, deflated by the price level

$$y = \phi(m - p)$$

(3)

where $\phi$ is the elasticity of aggregate demand with respect to real balances. Combining (2) and (3), we obtain firm $i$’s product demand:

$$y_i = \phi(m - p) - \varepsilon(p_i - p).$$

(4)

Product prices are set by the firm once wages have been determined and after both the firm’s realization of $\theta$ and the central bank’s choice of $m$. Firm $i$’s profit function is

$$\Pi_i = P_i Y_i - W_i L_i,$$

(5)

where the upper case letters denote the non-log levels of the variables. Combining (1) and (4) with (5) and maximizing $\Pi_i$ by $P_i$ gives us:

$$P_i = \left[ W_i^\alpha (Y^\varepsilon)^{(1-\alpha)} e^{-\theta} \right]^{\frac{1}{\alpha + \varepsilon(1-\alpha)}}.$$

(6)

Taking logs of (6) and using (2) and (3) gives us the associated product demand $y_i$. We combine this expression for $y_i$ with (1) to obtain firm $i$’s profit maximizing demand for labor:

$$l_i^d = \frac{\phi(m - p) - \varepsilon(w_i - p) + (\varepsilon - 1)\theta}{\alpha + \varepsilon(1 - \alpha)},$$

(7)

where $w_i$ is the nominal wage.
Each firm has an immobile pool of workers who are represented by a firm-specific union. This union has monopoly power over wage-setting within that firm. The desired supply of labor by union $i$ members, $l^s_i$, is assumed to be completely inelastic with its value normalized at one for convenience:

$$l^s_i = 1. \tag{8}$$

Therefore, $l^s_i$ is interpreted as the market-clearing level of employment within the respective individual labor market. Nominal wages are determined at the beginning of each period and are negotiated for single-period contracts. Employment demand is also determined within that same period. Union $i$ sets its nominal wage, $w_i$, to minimize the expected value of its loss function:

$$L^u_i = (w_i - p)^2 + \gamma l^2_i. \tag{9}$$

This particular equation form for specifying a union’s objectives is standard in literature about economy-wide consequences of union wage setting (Herrendorf & Lockwood, 1997), (Hutchinson & Walsh, 1998). The quadratic form implies that fluctuations in employment and the real wage around their target values are undesirable. The parameter $\gamma$ represents the relative weight each union places attaches to the employment objective before setting its nominal wage and determines the impact of any anticipated supply shocks on employment and the real wage. Equation (9) implies that the target values of both employment and the real wage are consistent with expected labor market clearing. Therefore, we assume that unions will not try and raise the real wage above its expected market-clearing value. If they did raise the real wage, the unemployment rate would increase, as would the inflation rate.

Wage determination occurs before implementation of monetary policy and prior to unions observing the actual value of the supply shock. Immediately before setting their nominal wages, all unions receive a noisy signal, $s$, of that shock:

$$s = \theta + u, \quad u \sim N(0, \sigma^2_u) \tag{10}$$

where $u$ is the realization of a noise term drawn from a zero-mean normal distribution with variance $\sigma^2_u$. Each union’s expectation of $\theta$, $E(\theta)$, is given by:

$$E(\theta|s) = \beta s, \quad \beta = \sigma^2_\theta/(\sigma^2_\theta + \sigma^2_u). \tag{11}$$

We interpret $s$ to be information provided to wage setters by the central bank. If the quality of information supplied by the central bank increases, the variance of $s$ will decrease so that the signal to the unions becomes more precise as to the exact nature of the shock. As the signal becomes more precise, $\beta$ will be larger.
and unions will attach more weight to the central bank’s signal when forming expectations.

The central bank is assumed to follow a monetary policy aimed at minimizing a conventionally-specified social loss function:

\[ L^* = \pi^2 + \lambda l^2, \quad l = \int_0^1 l_i \, di. \]  

(12)

In Equation (12), the social loss increases when inflation, \( \pi \), moves from its socially-optimal value of zero and when aggregate employment, \( l \), moves from its socially-efficient level, which is assumed to be the labor-market clearing level in individual markets. \( \lambda \) represents the relative weight placed on employment stabilization by the central bank when implementing monetary policy. We assume that the central bank’s objective function is public knowledge which removes any reputational considerations that might arise without that information. The events we have listed so far occur in the following order:

1. The supply shock \( \theta \) is realized.
2. The central bank observes \( \theta \) and the provides a noisy signal \( s \) to the private sector.
3. The unions determine wages \( w_i \).
4. The money supply \( m \) is set by the central bank.
5. The private sector observes \( \theta; p_i, p, l \) and \( y \) are determined.

In the above sequence, there are two main features to which we should pay special attention. First, we assume that monetary policy is implemented after wages have been set. This is a common depiction of monetary policy and wage determination in the literature, and not unreasonable, as intuitively monetary policy is more flexible than wage contracts.

Second, the central bank has a significant informational advantage in that they realize the true value of \( \phi \) much earlier than does the private sector. James and Lawler justify this asymmetry by claiming that central banks devote greater resources to forecasting and data-collecting than do private firms, resulting in better predictions of economic disturbances. In practice, the existence of central banks’ informational advantage seems to exist, at least in the United States. The Fed has access to data unavailable to the general public and their inflation estimates are preferable to those of market participants (Romer & Romer, 2000).
4.1 Equilibrium

In order to find the macroeconomic equilibrium we first have to determine the price level as a function of the nominal money stock, the average nominal wage, w, and θ. If employment is demand-determined, substituting (7) into (1) and then aggregating over firms gives us an expression for aggregate output:

\[ y = \alpha \left[ \frac{\phi(m - p) - (w - p)}{\alpha + (1 - \alpha)} \right] + \theta. \] (13)

By setting (13) equal to the aggregate demand equation (3), we are able to determine \( p \):

\[ p = \frac{\alpha w + \phi(1 - \alpha)m - \theta}{\alpha + \phi(1 - \alpha)}. \] (14)

The associated expression for aggregate employment is found by setting (3) equal to (1). Substituting in \( p \) and aggregating across firms gives us:

\[ \phi m - \phi \left[ \frac{\alpha w + \phi(1 - \alpha)m - \theta}{\alpha + \phi(1 - \alpha)} \right] = \alpha l + \theta. \] (15)

Solving for \( l \) and simplifying gives us the expression for aggregate employment:

\[ l = \frac{\phi m - \phi w + (1 - \phi)\theta}{\alpha + \phi(1 - \alpha)}. \] (16)

We can now consider the monetary policy decision of the central bank. We choose an \( m \) that minimizes the central bank’s social loss function, Equation (12), subject to (14) and (16). We set \( p_{-1} = 0 \) for convenience, which implies \( \pi = p \), so that we have:

\[ L^s = p^2 + \lambda l^2. \] (17)

Substituting in the expressions for aggregate price level and aggregate employment gives us:

\[ L^s = \left[ \frac{\alpha w + \phi(1 - \alpha)m - \theta}{\alpha + \phi(1 - \alpha)} \right]^2 + \lambda \left[ \frac{\phi m - \phi w + (1 - \phi)\theta}{\alpha + \phi(1 - \alpha)} \right]^2. \] (18)

Then we take the partial derivative of 18 with respect to \( m \) and set the resulting expression equal to zero. After simplifying, we end up with the solution to the central bank’s optimization problem:

\[ m = \frac{[\phi - \alpha(1 - \alpha)]w + [\lambda(1 - \phi) + (1 - \alpha)]\theta}{\phi[\lambda + (1 - \alpha)^2]}. \] (19)
Combining (19) with (14) and (16) determines the price level and aggregate employment as functions of the average nominal wage and a supply shock. The average nominal wage represents the aggregate outcome of individual union wage setting decisions.

Taking the nominal wages of all other unions as given, union $i$ chooses the nominal wage that will minimize the expected value of (9), subject to the expectation of the productivity shock that is identified in (11). Each union is aware of the objective function of the central bank, and is therefore able to infer its monetary policy reaction to non-zero realizations of $\theta$. However, as an individual union is a tiny part of the whole economy, the union perceives itself as having no influence on the setting of $m$. After substituting (7) into (9) and minimizing with respect to $w_i$, we can use (14) and (19) to obtain union $i$’s first order condition:

$$w_i = \frac{1}{\{\gamma \varepsilon^2 \alpha + \varepsilon(1-\alpha)^2\}[\lambda + (1-\alpha)^2]} \left\{ \lambda \gamma \varepsilon^2 + \lambda \alpha + \varepsilon(1-\alpha)^2 - \gamma \alpha \varepsilon(1-\alpha) \right\} w + [\alpha + \varepsilon(1-\alpha)] \{\gamma \varepsilon(1-\alpha) - \lambda \alpha \varepsilon(1-\alpha)\} \beta s.$$ (20)

Setting $w_i = w$ yields the unique symmetric Nash equilibrium value of $w$:

$$w = \frac{\{\gamma \varepsilon(1-\alpha) - \lambda \alpha + \varepsilon(1-\alpha)\} \beta s}{(1-\alpha) \{\gamma \varepsilon + (1-\alpha) \alpha + \varepsilon(1-\alpha)\}}.$$ (21)

Equation (21) shows that the expectation of a supply shock could cause unions to either increase or decrease their nominal wage. This is because any change in $E(\theta|s) = \beta s$ results from a change in $\theta$ observed by the central bank. The central bank may then change $\lambda$ in response to the shock, leading to an ambiguous relationship between $s$ and $w$. The factors determining the wage response to the expectation of a non-zero $\theta$ are central to the welfare implications of the quality of information provided by the central bank to wage setters.

The value of $p$ resulting from the interaction between union wage setting and monetary policy can be found using (21) and (19) with (14):

$$p = -\frac{\lambda \alpha + \varepsilon(1-\alpha)}{(1-\alpha) \{\gamma \varepsilon + (1-\alpha) \alpha + \varepsilon(1-\alpha)\}} \beta s - \frac{\lambda (\theta - \beta s)}{[\lambda + (1-\alpha)^2]}.$$ (22)

The same union and monetary policy interaction gives the following value of $l$, which comes from substituting (21) and (19) into (16):

$$l = \frac{\lambda \alpha + \varepsilon(1-\alpha)}{\{\gamma \varepsilon + (1-\alpha) \alpha + \varepsilon(1-\alpha)\}} \frac{\beta s}{(1-\alpha) \{\gamma \varepsilon + (1-\alpha) \alpha + \varepsilon(1-\alpha)\}} + \frac{(1-\alpha)(\theta - \beta s)}{[\lambda + (1-\alpha)^2]}.$$ (23)

Equations (22) and (23) show that changes in the price level and employment are comprised of two elements. The first element comes from the interaction
between monetary policy and the wage-setting decisions of unions in response to their expectation of $\theta$. The second element shows the central bank’s optimal policy reaction to the unions’ expectation errors.

The first term in (22) is referred to as the stochastic inflation bias:

$$\frac{\lambda[\alpha + \varepsilon(1 - \alpha)]\beta s}{(1 - \alpha)\left\{\gamma\varepsilon + (1 - \alpha)[\alpha + \varepsilon(1 - \alpha)]\right\}}$$

This is a result of the central bank’s desire to achieve greater employment stability from the wage determination process, assuming $E(\theta) \neq 0$. Once wages have been set with this expectation of $\theta$, the central bank has an incentive to adjust monetary policy in order to obtain its own optimal trade-off between price and employment stability. However, the unions are aware of this incentive, and so when making their wage decisions they incorporate the central bank’s anticipated attempts at decreasing unemployment into their choice of nominal wages.

If the central bank reacts to each supply shock without considering the long term implications of its policy decisions, the unions’ response to the anticipated supply shocks creates greater price volatility compared to a situation in which the central bank credibly precommits to an optimal policy rule. In addition to greater price level volatility, there is no reduction in employment variability if the central bank does not stick to a pre-announced monetary policy. This is because it is impossible for the central bank to use "surprise" changes in the money supply to reduce unemployment.

If the central bank changes the money supply after wage contracts are drawn up, for several subsequent periods the central bank will have drastically reduced credibility. The unions would then increase their wage demands in anticipation of unannounced central bank policy decisions, which would lead to an ugly cycle of ever increasing inflation. This would, of course, not improve productivity or the unemployment rate and is a major reason central banks today publish details of their policy plans and attempt to commit to certain courses of action. The exact impact a predicted supply shock will have on the economy depends on the extent to which is it predicted by the private sector, and therefore on the quality of information provided to the public by the central bank.

### 4.2 Welfare Effects

As better informed agents are more able to make decisions which benefit themselves, any improvement in the quality of information concerning supply shocks will be beneficial to the private sector.

After aggregating across unions and firms, we can find the expected union loss
by substituting (23) into equation (9):

\[ L = (w - p)^2 + \gamma \left[ \frac{\lambda[\alpha + \varepsilon(1 - \alpha)]\beta s}{\{\gamma\varepsilon + (1 - \alpha)[\alpha + \varepsilon(1 - \alpha)]\}} + \frac{(1 - \alpha)(\theta - \beta s)}{[\lambda + (1 - \alpha)^2]} \right]^2. \] (24)

Substituting (21) and (22) for \((w - p)\) in (24) and differentiating with respect to \(\sigma_u^2\) gives us:

\[
\frac{dE(L^u)}{d\sigma_u^2} = \frac{\{\gamma\varepsilon(1 - \alpha) - \lambda[\alpha + \varepsilon(1 - \alpha)]\}}{\{\gamma\varepsilon + (1 - \alpha)[\alpha + \varepsilon(1 - \alpha)]\}^2[\lambda + (1 - \alpha)^2]A_1}, (25)
\]

where

\[
A_1 = \left\{ \frac{\gamma\varepsilon(1 - \alpha) - \lambda[\alpha + \varepsilon(1 - \alpha)]}{\gamma\varepsilon + (1 - \alpha)[\alpha + \varepsilon(1 - \alpha)]}[\gamma + (1 - \alpha)^2] + 2\alpha[\lambda + (1 - \alpha)^2] \right\} \beta^2.
\]

Since the right hand side of (25) is ambiguous in sign, it is possible that an improvement in signal quality could increase the expected loss among unions. In other words, we want to see if unions would have a greater loss when \(s\) becomes closer in value to \(\theta\). Proposition 1 describes the conditions under which such a situation could arise:

Proposition 1. An improvement in the precision of the signal, \(s\), of the supply shock, \(\theta\), as represented by a reduction in the variance of the signal noise, \(\sigma_u^2\), will increase the expected union loss if and only if

\[
\frac{\alpha}{\varepsilon(1 - \alpha)} \left\{ 1 - \frac{2\gamma[\lambda + (1 - \alpha)^2]}{\lambda[\gamma + (1 - \alpha)^2]} \right\} < \frac{\gamma - \lambda}{\lambda} < \frac{\alpha}{\varepsilon(1 - \alpha)}. \]

We are also interested in the relationship between signal precision and the expected social loss so we substitute (22) and (23) into the central bank’s social loss function, (12). Taking expectations and differentiating with respect to \(\sigma_u^2\) gives us:

\[
\frac{dE(L^s)}{d\sigma_u^2} = \frac{\lambda\{\gamma\varepsilon(1 - \alpha) - \lambda[\alpha + \varepsilon(1 - \alpha)]\}}{(1 - \alpha)^2\{\gamma\varepsilon + (1 - \alpha)[\alpha + \varepsilon(1 - \alpha)]\}^2[\lambda + (1 - \alpha)^2]^2}A_2, (27)
\]

where

\[
A_2 = \left\{ \frac{\gamma\varepsilon(1 - \alpha) + [\lambda + 2(1 - \alpha)^2][\alpha + \varepsilon(1 - \alpha)]}{\gamma\varepsilon + (1 - \alpha)[\alpha + \varepsilon(1 - \alpha)]} \right\} \beta^2.
\]

Equation (27) directly implies:

Proposition 2. An improvement in the quality of information relating to the supply shock provided by the central bank to unions will increase the expected social loss if and only if:

\[
\frac{\gamma - \lambda}{\lambda} < \frac{\alpha}{\varepsilon(1 - \alpha)}. \] (28)
In other words, if $\gamma$ decreases enough or if $\lambda$ increases enough, the left hand side of the inequality decreases. Assuming the preferences attached to employment stability by both the unions ($\gamma$) and the central bank ($\lambda$) do not have a significant and direct effects on the degrees of economy of scale ($\alpha$) and the relative price elasticity of product demand ($\varepsilon$), if the central bank places a much greater emphasis on employment stability compared to the emphasis unions place on their employment objective, an increase in the quality of information released to the public will result in an increase in the expected social loss.

Therefore, there are theoretically situations in which improved central bank transparency can be detrimental to social welfare. Because of the monotonic nature of the relationship between $E(L^*)$ and $\sigma_u^2$ represented by (27), if the inequality identified by Proposition 2 is satisfied, zero disclosure will be optimal. However, there may also be instances where greater transparency would give rise to a smaller expected social loss, in which case full disclosure is optimal. We look at these possible situations more closely in the next section.

4.3 Interpretation and discussion

The surprising result that there are, in fact, some situations in which increased transparency results in reduced social welfare comes from two distinct forces, both of which increase in strength as the signal provided by the central bank to unions improves in quality. The first is associated with the relationship between the relative weights placed by unions and the central bank on employment stability compared to price level stability and the subsequent interaction between monetary policy and wage determination. This force has ambiguous effects in regards to how greater central bank transparency affects social welfare but is always beneficial for unions. The second force comes from an externality which characterizes wage determination and is always detrimental to both society and unions. Because its consequences would be fully internalized by a single, economy-wide union, its adverse impact originates from uncoordinated wage setting. The detrimental impact of the second force decreases as the product market becomes more competitive.

James and Lawler’s model shows that, to make sure an increase in transparency will be beneficial to society, unions must have an incentive to value employment stability more than the central bank does. In fact, if unions only care about employment, full transparency will be the most beneficial situation and will allow complete stabilization of both employment and price levels.
4.3.1 The consequences of transparency with a perfectly competitive goods market

By considering the limiting case of a perfectly competitive goods market ($\varepsilon \to \infty$), we can eliminate the influence of the externality caused by uncoordinated wage setting and focus on the relationship between the central bank and the unions. It is clear that the condition in Proposition 1 will never be satisfied since it reduces to

$$0 < \frac{\gamma - \lambda}{\lambda} < 0$$

when the goods market operates under perfect competition. If the goods market is perfectly competitive, an improvement in signal quality can never be detrimental from the unions’ point of view.

There are three situations which may arise under perfect competition in Proposition 2: $\gamma = \lambda$, $\gamma < \lambda$, and $\gamma > \lambda$.

1) $\gamma = \lambda$: Suppose that $\gamma = \lambda$ and that wage setters are completely uninformed about the true value or occurrence of $\theta$. If the nominal wage remains constant, movements in the price level as the central bank responds to supply shocks will be exactly the same as movements in the real wage. Therefore, when the central bank and the unions both place the same weight on employment stability, the implementation of monetary policy will achieve each union’s desired trade-off between real wage and employment stability. This symmetry comes about as a by-product of achieving society’s optimal trade-off between price level and employment. Each union is aware that if they place the same weight on employment stability as the central bank does, when the central bank implements monetary policy the union’s desired real-wage-employment-stability trade-off will occur. The optimal response of unions to any signal of a supply shock is to keep the nominal wage constant. In this case, macroeconomic outcomes and the resulting expected values of both the social and union loss functions are independent of signal quality.

2) $\gamma < \lambda$: When $\gamma < \lambda$, the monetary policy implemented by the central bank creates too much employment stability at the expense of excessive real wage variability in the unions’ point of view. Any signal concerning a non-zero $\theta$ will motivate the unions to change the nominal wage as they try to achieve their desired trade-off between employment and wage stability. While the movement in the nominal wage is beneficial for the unions, increased transparency is detrimental to social welfare, as it increases the variability of both the employment level and the price level. Frequent variations in optimal wage and employment levels impose costs on society in general, as it is expensive for businesses to be constantly adjusting prices and wage contracts.

In the extreme case where $\gamma = 0$, unions are only concerned with stabilizing the real wage. This leads to an absence of any real wage adjustment to counteract the
supply shock’s impact. In this situation, $\theta$ has its maximum effect on employment and, through the subsequent policy response by the central bank, the price level.

3) $\gamma > \lambda$: When unions place a greater relative value on employment stability compared to the central bank, greater central bank transparency is beneficial to society. If the nominal wage is constant and $\gamma > \lambda$, the outcome of stabilization policy results in too little real wage adjustment and too high a degree of employment variability for the unions’ liking. Therefore, any information concerning the realization of supply shocks will lead to a nominal wage response directed at attaining greater employment stability. This benefits both the unions and the general public, as society gains from the reduction in employment volatility and from the fall in stochastic inflation bias. As $\gamma \rightarrow \infty$, union concerns move solely towards employment and full transparency will allow complete stabilization of both employment and prices.

4.3.2 Union wage setting with monopolistic competition

Up until now, we have only analyzed the consequences of central bank transparency when the goods market is perfectly competitive. When the market is characterized instead by monopolistic competition, an externality present in union wage setting comes into play. It arises because each union regards its influence on the price level, and hence on aggregate demand, as negligible.

The perceived trade-off between employment and the real wage at the individual union level differs from that which actually prevails at the aggregate level. Following the observation of any signal indicating a supply shock, the aggregate adjustment of the nominal wage departs from the efficient response. Unions change their level of employment too much while adjusting the real wage too little.

It is easiest to see that the unions’ collective response is inefficient we let $\gamma = \lambda$. If unions are initially uninformed about the true nature of $\theta$, stabilization policy achieves the optimal outcome in response to shocks from the perspectives of both unions and the general public. When unions, as a group, believe their actions have no impact on the price level, the economic equilibrium is no longer independent of whether a signal is provided to unions. Any information relating to $\theta$ now leads to unions increasing the nominal wage. This happens because each union is trying to improve on the outcome associated with an unchanged nominal wage. They think that an increase in the real wage for their small number of workers (compared to the total number of workers in the economy-wide labor force) will not affect the wages of workers in other unions and certainly will not affect the price level. Therefore, any signal released by the central bank of an economic shock creates a movement away from the efficient equilibrium. There is a larger-than-optimal adjustment in employment and the magnitude of the adjustment increases as the signal’s precision increases. Greater transparency is associated with more volatile
employment and will result in higher than expected losses for both unions and society.

The inefficient adjustments of the price level and employment can also occur when \( \gamma \neq \lambda \). The negative impact on social welfare arising from the wage setting externality increases when \( \gamma < \lambda \). A smaller relative weight placed on employment stability by unions means greater variability in employment and a larger stochastic inflation bias as unions become better informed. Greater signal precision will enhance social welfare only if \( \gamma > \lambda \). A smaller relative weight placed on employment stability by unions means greater variability in employment and a larger stochastic inflation bias as unions become better informed. Greater signal precision will enhance social welfare only if \( \gamma > \lambda \). From Proposition 2, quality of information provided by the central bank improves social welfare if and only if the weight placed on employment stability by unions is:

\[
\gamma < \frac{\lambda[\alpha + \varepsilon(1 - \alpha)]}{\varepsilon(1 - \alpha)}. \tag{29}
\]

If the two sides in equation 29 were equal, the larger relative weight placed on employment by unions would be just enough to compensate for the effects of the wage setting externality on employment variability. However, for all \( \gamma \) less than this minimum value, we end up with \( dE(L^)/d\sigma_u^2 < 0 \).

5 Heterogeneous Private Beliefs

5.1 Heterogeneous private information and central bank disclosure

A logical next step in the evaluation of the utility of central bank information is to examine what happens to employment and price levels when unions have differing private information sets. As each firm in any large economy has different research capabilities and priorities it is more realistic to assume each one receives a slightly different view of the economic shock, or a different \( s \). While all firms receive the same signal from the central bank, each one may have their own economic forecasters who can give additional useful information or could be in an industry that is a good predictor of future changes in supply.

A key factor in generating Propositions 1 and 2 is the externality arising from uncoordinated wage decisions of individual unions. This externality would be at its strongest if each union knew with certainty the realized value of any shock prior to setting its nominal wage. Incorporating union-specific signals relating to the value of \( \theta \) into our analysis would introduce an additional externality, intrinsic to the information process but confined to situations of imperfect knowledge.

The uncoordinated-wage-decision externality arises as a result of agents’ actions being strategic complements. If each union, before making its wage decision, observes its own private signal in addition to any information provided by the
central bank, the information content of the public and private signals will be exploited inefficiently. Distortions other than incomplete information create a gap between the complete-information equilibrium and the first best equilibrium, leading to a decrease in welfare with both private and public information. A reduction in noise (or smaller variances for the public and private signals) brings equilibrium activity closer to its complete-information equilibrium but moves it away from the first-best level (Angeletos & Pavan, 2007).

The consequences of this inefficiency will, in most cases, lead to a situation in which greater transparency is undesirable. Any information about $\theta$ disclosed by the central bank will limit the effectiveness of policy intervention aimed at reducing the frequency and magnitude of employment fluctuations. The concurrent induced wage responses of individual unions will only partially compensate for the reduced effectiveness of monetary policy.

If the central bank realizes the true value of $\theta$ before releasing any information and implementing its policy setting, these results regarding the desirability of transparency remain the same. When agents have access to perfect information, any sources of imperfect information will be ignored. Therefore, when full transparency is optimal in the absence of heterogeneous private information, full transparency will still be optimal even when unions observe their own signals regarding the supply shock, as the private signals will be redundant. In the "borderline" case examined previously, where the social loss is independent of the degree of transparency, unions will still anticipate that the central bank will achieve the unions' desired trade-off between employment stability and the real wage level. There would be no reason to change the nominal wage in response to information received about $\theta$, no matter its source. Because the informational externality associated with heterogeneous private information tends to exacerbate the detrimental effects arising from central bank transparency, it follows that, in cases where zero disclosure is optimal in the absence of private union signals, the existence of private signals that the unions pay attention to will inevitably increase the likelihood against full central bank disclosure being the optimal situation.

The potentially harmful consequences of central bank transparency, in combination with private heterogenous information, become more significant when the central bank itself is imperfectly informed about the true nature of $\theta$. When the central bank is not operating under perfect information, each union will adjust its nominal wage in response to its private signal, even if the central bank releases all of its own information immediately. As complete transparency does not impart perfect knowledge of the value of the supply shock, the inefficiency stemming from the use of available information will strengthen the detrimental effects caused by increased transparency. Therefore, union-specific signals relating to the supply shock will extend the range of parameter value combinations for which zero
disclosure is socially optimal. For the cases in which our analysis has identified full transparency to be optimal, heterogeneous private information introduces an optimal strategy not present in our framework, that of an intermediate degree of transparency. Though this can occur only for certain parameter value combinations, it is consistent with several analyses of central bank disclosure discussed in previous sections.

5.2 Modeling Idiosyncratic Shocks

In order to see how heterogeneous information affects wage, price and employment levels, we examine a two-stage model which is essentially a synthesis of the model previously discussed by James and Lawler and a model developed by Angeletos and La’O (2009). Instead of basing their predictions about aggregate economic activity on uniform information, firms and unions are located in separate sectors, or "islands".

Each island is subject to technology shocks, which have both an aggregate and an idiosyncratic component. It is assumed that local (i.e. sector-specific) productivity is distributed log-normally in the cross section of islands and that firms and unions know the economic fundamentals of their own sector perfectly. From this information, local agents can obtain a basic idea about the state of the economy as a whole while not knowing exactly how much the aggregate economy is expanding or contracting.

The central bank is perfectly informed about both the levels of employment and inflation in the islands and about the state of the overall economy. In order to manipulate the economy’s price and employment levels to meet its own objectives, the central bank releases information about economic disturbances to the public.

5.2.1 Setup

There is a representative household which supplies workers to all the labor unions in the economy. There is a continuum of islands (which can be thought of as the different sectors in the economy) indexed by $i \in [0, 1]$, each inhabited by a representative firm which produces a differentiated good or commodity. Information is symmetric within an island, but is asymmetric between islands. Each firm has an immobile pool of workers, represented by an individual firm-specific union that supplies the labor to that firm. Firms and unions in the same sector are operating under perfect competition with each other, rather under monopolistic competition as in James & Lawler’s model.

There are 2 stages. During Stage 1, the household sends a worker to the unions on each of the islands. Unions and firms have perfect information about local productivity but imperfect and dispersed information about aggregate productivity.
Local labor markets open and employment and production choices take place so that local labor markets clear.

Once employment and production choices are sunk, workers return to their households and the economy moves to the next stage. In Stage 2, all information that was previously dispersed becomes common knowledge and commodity markets open. Quantities are pre-determined by the exogenous productivities and employment choices made during Stage 1, but prices adjust to clear product markets.

The utility function of the household is given by

\[ u = \chi \left[ U(C) - \int \Gamma(L_i) di \right] i. \]  

(30)

\( L_i \) is the labor of the worker who is located on island \( i \) during Stage 1 and \( C \) is a composite of all commodities that the household purchases and consumes during Stage 2. \( C \) is given by the Dixit-Stiglitz aggregator function:

\[ C = \left[ \int c_i^{\frac{1}{z-1}} di \right]^{\frac{z-1}{z}}, \]

where \( z \) is the elasticity of substitution across different goods. This CES structure is stated in order to generate a situation in which the decision of island \( i \) is transmitted to the aggregate economy. The household essentially "outsources" labor to the unions and has slightly different objectives compared to the unions.

Union \( i \)'s loss function is

\[ L_u^i = (w_i - p)^2 + \gamma l_i^2, \]  

(31)

the same as it was in James & Lawler's model.

The output of the representative firm on island \( i \) is given by

\[ Q_i = A_i(L_i)^\alpha, \]

or in logarithmic form,

\[ q_i = \alpha l_i + a_i, \]  

(32)

where \( 0 < \alpha < 1 \). This is the same as the output function in Equation (1), where the uniform shock \( \theta \) is now the idiosyncratic shock \( a_i \). The firm’s realized profits are given by

\[ \Pi_t = P_i Q_i - W_i L_i. \]  

(33)

It is assumed that households own equal shares of all firms in the economy. The firm’s objective is to maximize expected shareholder value, which is \( \frac{U(C)}{P} \Pi_t \).
Although workers cannot move across islands within a period, commodities are traded beyond the islands’ geographical boundaries. The clearing conditions for product markets are given by
\[ c_i = Q_i \forall i \]
such that
\[ a_i \equiv \log A_i = \bar{a} + \xi_i, \]
where \( \bar{a} \) is the common component drawn by nature and \( \xi_i \sim N(0, 1/\kappa_\xi) \) is the idiosyncratic component. Although unions and firms don’t know the exact value of the shock, it is common knowledge that \( \bar{a} \) is log-normally distributed with mean \( \mu \) and variance \( 1/\kappa_0 \):
\[ \bar{a} = \mu + \epsilon, \quad \epsilon \sim N(0, 1/\kappa_0). \] (34)
Only the central bank knows the exact value of \( \bar{a} \) before wages are determined. Agents see the signals \( x_i \) and \( y_i \), which they know are distributed:
\[ x_i = \bar{a} + u_i \quad \text{and} \quad y_i = \bar{a} + \eta \]
with
\[ u_i \sim N(0, 1/\kappa_x) \quad \text{and} \quad \eta \sim N(0, 1/\kappa_y). \]
Firm \( i \) finds its conditional expectation of \( \bar{a} \) given the other signals it observes, by calculating the conditional expectation of \( \bar{a} \):
\[ E_i[\bar{a}|\mu, 1/\kappa_0, a_i, x_i, y_i]. \]
If we let \( x_i = \mu + \epsilon + u_i \) we can see that \( a_i \) and \( x_i \) are correlated:
\[
E[(\bar{a} - \mu)(x_i - \mu)] = E[(\bar{a} - \mu)(\mu + u_i + \epsilon - (\mu + \epsilon)\mu - \mu(u_i + \epsilon) + \mu^2)] \\
= E[u_i \epsilon] + E[\epsilon^2] \\
= 1/\kappa_0.
\]
The individual signal \( x_i \) can be rewritten to contain all of the information in both \( \bar{a} \) and \( y_i \):
\[ x_i = \mu + \epsilon + u_i + \eta, \] (35)
so that \( x_i \sim N(\mu, 1/\kappa_0 + 1/\kappa_x + 1/\kappa_y) \). Denote
\[ A = \begin{bmatrix} \bar{a} \\ x_i \end{bmatrix} \]
which is multivariate normal with expected value $EA = [\mu \mu]'$ and covariance matrix

$$
\Sigma = E(A - EA)(A - EA)'
$$

$$
= E \begin{bmatrix}
(\bar{a} - \mu)(\bar{a} - \mu) & (\bar{a} - \mu)(x_i - \mu) \\
(x_i - \mu)(\bar{a} - \mu) & (x_i - \mu)^2
\end{bmatrix}
$$

$$
= E \begin{bmatrix}
\epsilon^2 & \epsilon(\epsilon + u_i + \eta) \\
(\epsilon + u_i + \eta)\epsilon & (\epsilon + u_i + \eta)^2
\end{bmatrix}
$$

$$
= \begin{bmatrix}
\frac{1}{\kappa_0} & \frac{1}{\kappa_0} \\
\frac{1}{\kappa_0} & \frac{1}{\kappa_x + \frac{1}{\kappa_y}}
\end{bmatrix}
$$

The conditional expectation $E(\bar{a}|\mu = x_i)$ is given by:

$$
E(\bar{a}|\mu = x_i) = \mu + \Sigma_{12}\Sigma_{22}^{-1}(x_i - \mu)
$$

$$
= \mu + \frac{1}{\kappa_0} \left( \frac{1}{\kappa_0} + \frac{1}{\kappa_x + \frac{1}{\kappa_y}} \right) [x_i - \mu]
$$

$$
= \mu + \frac{\kappa_x\kappa_y + \kappa_0\kappa_y + \kappa_0\kappa_x}{\kappa_0(\kappa_0 + \kappa_x + \kappa_y)} [x_i - \mu]
$$

The expected value of $x_i$ is $\mu$, so the term with $[x_i - \mu]$ becomes zero. Let $y_i$ to be equal to $\mu + \epsilon + u_i + \eta$, which is the same way we defined $x_i$ in equation 35. This means we can substitute $y_i$ for $x_i$ in the term with $\kappa_y$ as the numerator. Finally, we end up with sector i’s conditional expectation of aggregate productivity:

$$
E(\bar{a}|\mu = x_i) = \mu + \frac{\kappa_0}{\kappa_0 + \kappa_x + \kappa_y} [x_i - \mu] + \frac{\kappa_x}{\kappa_0 + \kappa_x + \kappa_y} y_i,
$$

(36)

In order to see how $\xi_i$, the idiosyncratic component of $a_i$, is included in $x_i$, write $x_i$ as:

$$
x_i = \frac{\kappa_0}{\kappa_0 + \kappa_x + \kappa_y} \bar{a} + \frac{\kappa_x}{\kappa_0 + \kappa_x + \kappa_y} x_i + \frac{\kappa_y}{\kappa_0 + \kappa_x + \kappa_y} y_i,
$$

(37)

where $\bar{x}_i = \bar{a} + \xi_i$ is some other private signal observed by sector i with $\xi_i \sim N(0, 1/\kappa_\xi)$. If we let

$$
x_i = \bar{a} + \xi_i + u_i + \zeta_i,
$$

$$
A = [a_i x_i]',
$$

$$
EA = [\bar{a} \bar{a}]',
$$

31
the corresponding covariance matrix is:

\[
\Sigma = \begin{bmatrix}
\frac{1}{\kappa_\xi} & \frac{1}{\kappa_\zeta} \\
\frac{1}{\kappa_\zeta} & \frac{1}{\kappa_\xi + \kappa_\zeta}
\end{bmatrix}.
\]

Then it is easy to see how \( \xi \) is included in \( x \):

\[
x_i = \frac{\kappa_\xi}{\kappa_\xi + \kappa_\zeta} (\underline{\pi} + \xi_i) + \frac{\kappa_\zeta}{\kappa_\xi + \kappa_\zeta} (\underline{\pi} + \zeta_i)
\]

\[
= \underline{\pi} + \left( \frac{\kappa_\xi}{\kappa_\xi + \kappa_\zeta} \xi_i + \frac{\kappa_\zeta}{\kappa_\xi + \kappa_\zeta} \zeta_i \right)
\]

\[
= \underline{\pi} + u_i,
\]

where \( u_i = \frac{\kappa_\xi}{\kappa_\xi + \kappa_\zeta} \xi_i + \frac{\kappa_\zeta}{\kappa_\xi + \kappa_\zeta} \zeta_i \). This implies that \( u_i \sim N(0, 1/\kappa_x) \) with \( \kappa_x = \kappa_\xi + \kappa_\zeta \).

5.2.2 Finding the Equilibrium

The information set, or "type," of any island \( i \) is denoted by \( \omega_i \), where

\[
\omega_i = (a_i, x_i, y_i).
\]

The aggregate state of the economy is given by the cross-sectional distribution of \( \omega_i \), denoted by \( \Omega \).

Definition 1. An equilibrium consists of an employment strategy \( L(\omega) \), a production strategy \( Q_\omega \), a wage function \( W(\omega) \), an aggregate output function \( Q_\Omega \), an aggregate employment function \( L_\Omega \), a price function \( P_{\omega, \Omega} \) and a consumption strategy \( c(P, Q) \) such that the following are true:

1. The aggregate price is normalized so that

\[
P_\Omega \equiv \left[ \int_0^1 P_{\omega, \Omega}^{1-z} dF(\omega|\Omega) \right]^{\frac{1}{1-z}} = 1, \forall \Omega_i
\]

2. The quantity \( c(P, Q) \) is the household’s optimal demand for any commodity whose price is \( P \) and aggregate output is \( Q \).

3. The quantities \( L(\omega) \) and \( Q_\omega \) are optimal from the perspective of the representative firm on island \( \omega \), where \( Q_\omega = A(\omega) L(\omega) \).

4. The local wage \( W(\omega) \) minimizes union \( \omega \)'s expected loss on island \( \omega \).
5. When the aggregate economy’s state is $\Omega$, the price that clears the market for the good from island $\omega$ is $P_{\omega,\Omega}$, and the aggregate output and employment indices are, respectively,

$$Q_\Omega = \left[ \int_0^1 Q_\omega^{z-1} dF(\omega|\Omega) \right]^{\frac{1}{z-1}} \quad \text{and} \quad L(\Omega) = \int_0^1 L(\omega)dF(\omega|\Omega)$$

The first condition means that the numeraire for the economy is the CES composite $C$. The rest of the conditions represent a hybrid of a Walrasian equilibrium for the complete-information exchange economy that occurs during Stage 2 once production choices are fixed, and a Bayesian-Nash equilibrium for the incomplete-information game played among different islands in Stage 1.

To solve for the equilibrium, we first consider how the economy behaves in Stage 2, when all information is common knowledge and consumption takes place. The optimal demand of the representative consumer for the good from island $\omega$ whose price is $P_{\omega,\Omega}$ is given by

$$P_{\omega,\Omega} = \left( \frac{Q_\omega}{Q_\Omega} \right)^{\frac{1}{\alpha}}. \quad (38)$$

We have normalized the price level to $P_\Omega = 1$.

During Stage 1, firms set their optimal labor demands and unions set their optimal wage demands. Firms want to maximize their profits conditional on their information set, i.e.

$$\max \mathbb{E}[PQ - WL_i|\omega]. \quad (39)$$

Substituting $\left[ Q_\omega / A(\omega) \right]^{\frac{1}{\alpha}}$ into (39) for $L_i$ gives us

$$\max \mathbb{E} \left[ \left( P_{\omega,\Omega}Q_\Omega - W(\omega) \left( \frac{Q_\omega}{A(\omega)} \right)^{\frac{1}{\alpha}} \right) |\omega \right]. \quad (40)$$

Taking the FOC of (40) with respect to $Q$, we get

$$\mathbb{E} \left[ \left( P_{\omega,\Omega} - \frac{1}{\alpha} W(\omega) \left( \frac{Q_\omega}{A(\omega)} \right)^{\frac{1}{\alpha}-1} \frac{1}{A(\omega)} \right) |\omega \right] = 0,$$

which simplifies to:

$$\mathbb{E} \left[ \left( P_{\omega,\Omega} - \frac{1}{\alpha} W(\omega)L(\omega) \frac{1}{Q_\omega} \right) |\omega \right] = 0. \quad (41)$$
Solving (41) for \( L_i \) gives us
\[
L_i = \alpha Q_i \left( \frac{P_i}{W_i} \right), \text{ or, in log form,}
\]
\[
l_i = \log \alpha + q_i + p_i - w_i. \tag{42}
\]

Union \( i \) sets its nominal wage to minimize the expected value of its loss function:
\[
\min_{w_i} \mathbb{E} \left[ (w_i - p)^2 + \gamma l_i^2 \right], \tag{43}
\]
where the labor supply \( l_i \) is given by (42). Taking the derivative of (43) with respect to the nominal wage gives us:
\[
\mathbb{E}\left\{2(w_i - p) - 2\gamma [\log \alpha + q_i + p_i - w_i] \right\} = 0.
\]

After solving for \( w_i \), we end up with union \( i \)'s optimal wage with the price level normalized to unity:
\[
W_i = L_i^\gamma. \tag{44}
\]

The unions’ loss-minimizing wage depends on the firms’ profit-optimizing demand for labor and the relative weight each union attaches to the employment objective.

Substituting the equilibrium wage from (44) and the equilibrium price from (38) into (41) and using the definition of labor from the production function, we get
\[
\mathbb{E} \left[ \left( \frac{Q_\omega}{Q_\Omega} \right)^{-\frac{1}{2}} - \frac{1}{\alpha} \left( \frac{Q_\omega}{A(\omega)} \right)^{\frac{1}{2} \gamma + 1} \frac{1}{Q_\omega} \right] = 0. \tag{45}
\]

Solving for \( Q_\omega \) gives us the following proposition:

**Lemma 1.** In any equilibrium, the strategy \( Q : \Omega \to \mathbb{R} \) is the fixed point to the following functional equation:
\[
Q_\omega^{\frac{w_\omega^1}{w_\omega^2} + \frac{1}{2} - 1} = \alpha A(\omega)^{\frac{w_\omega^0}{w_\omega^2}} \mathbb{E} \left[ Q_\Omega^\frac{1}{2} \right] \forall \omega, \tag{46}
\]

with
\[
Q_\Omega = \left[ \int_0^1 Q_\omega^{\frac{w_\omega^1}{w_\omega^2}} d\Omega(\omega) \right]^{\frac{w_\Omega^1}{w_\Omega^1}} \forall \Omega.
\]

Lemma 1 says that combining the production strategy \( Q_\omega \) with the output function \( Q_\Omega \) returns the information set \( \omega_i = (a_i, x_i, y_i) \).
5.2.3 Best-Response Function

Suppose that, conditional on the type of island, the posterior of $Q\omega$ is log-normal and its variance is independent of $\omega$. Taking the log of (46) and using the log-normality of $Q$, we infer that the equilibrium production strategy must satisfy

$$
\left(\frac{\gamma + 1}{\alpha} + \frac{1}{z} - 1\right) \log Q_\omega = \log \alpha + \frac{\gamma + 1}{\alpha} \log A(\omega) + \log \{\exp(\mathbb{E}[\log Q_\omega])
\right. $$

$$
\left. + \frac{1}{2}(\sigma[\log Q_\omega])^2\}, \quad (47)
$$

where $\sigma$ is the standard deviation of $\log Q_\omega$. The right-hand side of the above equation includes three terms due to the properties of log-normally distributed variables. The expected value of $\log Q_\omega$ comes from:

$$
\mathbb{E}[\log Q_\omega] = \exp(\text{mean of } [\log Q_\omega] + 1/2(\text{variance of } [\log Q_\omega])).
$$

Simplifying (47), we get:

$$
\left(\frac{\gamma + 1}{\alpha} + \frac{1}{z} - 1\right) \log Q_\omega = \log \alpha + \frac{\gamma + 1}{\alpha} \log A(\omega) + \frac{1}{z}\mathbb{E}[\log Q_\omega]
$$

$$
+ \frac{1}{2} \left(\frac{1}{z}\right)^2 \text{Var}[\log Q_\omega],
$$

where $\text{Var}[\log Q_\omega] = \text{Var}[\log Q_\omega]$ is a constant. After dividing both sides by $(\frac{\gamma + 1}{\alpha} + \frac{1}{z} - 1)$ we obtain the following proposition:

**Proposition 3.** The equilibrium production strategy is a unique fixed point to

$$
\log Q_\omega = \zeta + (1 - \Psi_0)\Psi_1 a(\omega) + \Psi_0 \mathbb{E}[\log Q_\omega] \forall \omega \quad (48)
$$

with

$$
\Psi_0 \equiv \frac{\frac{1}{z}}{\frac{\gamma + 1}{\alpha} + \frac{1}{z} - 1} < 1 \quad \text{and} \quad \Psi_1 \equiv \frac{\frac{\gamma + 1}{\alpha}}{\frac{\gamma + 1}{\alpha} - 1} > 0
$$

where $\Psi_0$ is the degree of strategic complementarity and

$$
\zeta \equiv \frac{1}{\frac{\gamma + 1}{\alpha} + \frac{1}{z} - 1} \left\{ \log \alpha + \frac{1}{2} \left(\frac{1}{z}\right)^2 \text{Var}[\log Q_\omega] \right\}
$$

is a constant.

This gives us a best-response-like function for the equilibrium output produced on any island that is also a game-theoretic interpretation for the equilibrium of the
economy. The general equilibrium reduces to the Bayesian-Nash equilibrium of a particular incomplete-information game. The relevant "players" for this game are the different sectors, or islands, of the economy. Their "actions" are the production levels in each island and their "types" are the local information sets. From this information we can determine each player’s best response from Equation (48). From (48), we can see that the coefficient $\Psi_1$ must be positive while $\Psi_0$ can be positive or negative. $\Psi_1$ determines the elasticity of local output to variation in local productivity. $\Psi_0$ determines the elasticity of local output to variation in expected aggregate output.

5.2.4 Strategic Complementarity

The degree of strategic interaction among islands is controlled by $\Psi_0$. When $\Psi_0 > 0$, this can be interpreted as the degree of strategic complementarity, or, when $\Psi_0 < 0$, the degree of substitutability. When $0 < \Psi_0 < 1$, it measures the degree of strategic complementarity in production choices. Higher expected aggregate income implies a higher expected demand for the products of each sector, increasing the returns to each island. This "demand-side" effect is generic to any economy featuring Dixit-Stiglitz preferences and is the source of strategic complementarity. The degree of the effect is controlled by $z$, which represents the elasticity of substitution across commodities of different sectors. As the fraction $1/z$ increases, there is more complementarity between goods, making the demand for any one good increasingly inelastic. $\Psi_0 > 0$ is the most empirically likely case for business-cycle frequencies.

Note that $\Psi_0$ depends not only on $z$, but also on $\gamma$ and $\alpha$. As unions place a lower weight on employment stability relative to price level stability (leading to a lower $\gamma$), $\Psi_0$ increases. The real wage does not change even with expectations of increasing aggregate output, so firms can keep wages low while hiring more workers, leading to an increase in firms’ profits. The same incentive applies when $\alpha$ is large, meaning that production is increasing in an approximately linear fashion. A lower $\gamma$ and a higher $\alpha$ contribute to greater strategic complementarity. The parameters $\gamma$ and $\alpha$ also affect how sensitive the elasticity of local output is to variations in local productivity, given by $\Psi_1$, and matter for equilibrium allocations even when strategic complementarity is low. Since $z$ only affects $\Psi_0$, it makes sense to think of strategic complementarity as being controlled by $z$, the elasticity of substitution or by the strength of trade linkages across sectors.

Given the log-normal specification for the shock and information structure, we reach the following closed-form solution for equilibrium production:

**Proposition 4.** The equilibrium level of output is given by

$$\log Q_\omega = \varphi_0 + \varphi_a a + \varphi_x x + \varphi_y y$$
where

\[
\varphi_a = (1 - \Psi_0)\Psi_1 \\
\varphi_x = \left\{ \frac{(1 - \Psi_0)\kappa_x}{(1 - \Psi_0)\kappa_x + \kappa_y + \kappa_0} \right\} \Psi_0 \Psi_1 \\
\varphi_y = \left\{ \frac{(1 - \Psi_0)\kappa_y}{(1 - \Psi_0)\kappa_x + \kappa_y + \kappa_0} \right\} \Psi_0 \Psi_1
\]

and aggregate output is given by

\[
\log Q_\Omega = \varphi'_0 + \varphi_a \bar{a} + \varphi_y \eta
\]  

(49)

where

\[
\varphi_a = \varphi_a + \varphi_x + \varphi_y \quad \text{and} \quad \varphi_0 = \varphi_y
\]

Proof. We begin with a guess that the equilibrium production strategy occurs in the log-linear form

\[
q(a, x, y) = \varphi_0 + \varphi_a a + \varphi_x x + \varphi_y y
\]

for some coefficients \((\varphi_0, \varphi_a, \varphi_x, \varphi_y)\). If we plug \(Q_\omega\) into (49) we get:

\[
\log Q_\Omega = \varphi'_0 + (\varphi_a + \varphi_x + \varphi_y) \bar{a} + \varphi_y \eta
\]

\[
= \varphi'_0 + (\varphi_a + \varphi_x) \bar{a} + \varphi_y (\bar{a} + \eta)
\]

\[
= \varphi'_0 + (\varphi_a + \varphi_x) \bar{a} + \varphi_y y
\]

where

\[
\varphi'_0 = \varphi_0 + \frac{1}{\mathbb{E}[\bar{a}]} \left( \frac{z - 1}{z} \right) \frac{1}{2} (\varphi_a + \varphi_x)^2 \mathbb{E}[\bar{a}] (\sigma_a^2) \quad (50)
\]

In (50), \((z - 1)/z\) comes from the outer exponent in the Dixit-Stiglitz aggregator function. We divided (50) by the expectation of the aggregate supply shock as \(x\) is different for each sector. After computing the mean of private information over all the sectors and we obtain the expressions for the mean and variance of \(\mathbb{E}[\bar{a}]\) from the log-normality specification of the shock and information structure. Simplifying (50) further, we end up with:

\[
\varphi'_0 = \varphi_0 + \left( \frac{z - 1}{z} \right) \frac{(\varphi_a + \varphi_x)^2}{2} \left[ \frac{\varphi_x^2}{\kappa_x} + \frac{\varphi_a^2}{\kappa_a} + 2\frac{\varphi_a \varphi_x}{\kappa_a \kappa_x} \right]
\]

It follows that \(Q_\Omega\) is log-normal with expected value

\[
\mathbb{E}[\log Q_\Omega | \omega] = \varphi'_0 + (\varphi_a + \varphi_x) \mathbb{E}[\bar{a}(\Omega) | \omega] + \varphi_y y
\]  

(51)

and variance

\[
\text{Var}[\log Q_\Omega | \omega] = (\varphi_a + \varphi_x)^2 \left( \frac{1}{\kappa_0 + \kappa_x + \kappa_y} \right),
\]  

(52)
where
\[
E[\bar{a}(\Omega)|\omega] = \frac{\kappa_0}{\kappa_0 + \kappa_x + \kappa_y} \mu + \frac{\kappa_x}{\kappa_0 + \kappa_x + \kappa_y} x + \frac{\kappa_y}{\kappa_0 + \kappa_x + \kappa_y} y. \tag{53}
\]
Substituting (53) into (51) gives us:
\[
E[\log Q_{\Omega}|\omega] = \varphi'_0 + (\varphi_a + \varphi_x) \left( \frac{\kappa_0}{\kappa_0 + \kappa_x + \kappa_y} \mu + \frac{\kappa_x}{\kappa_0 + \kappa_x + \kappa_y} x + \frac{\kappa_y}{\kappa_0 + \kappa_x + \kappa_y} y \right) + \varphi_y y \quad \tag{54}
\]
Substituting (54) into (48) leads to:
\[
\log Q_\omega = \zeta + (1 - \Psi_0) \Psi_1 a + \Psi_0 \left\{ \varphi'_0 + \varphi_y y + (\varphi_a + \varphi_x) \left( \frac{\kappa_0}{\kappa_0 + \kappa_x + \kappa_y} \mu + \frac{\kappa_x}{\kappa_0 + \kappa_x + \kappa_y} x + \frac{\kappa_y}{\kappa_0 + \kappa_x + \kappa_y} y \right) \right\} \quad \tag{55}
\]
In order for (55) to be of the form \( \log Q(a, x, y) = \varphi_0 + \varphi_a a + \varphi_x x + \varphi_y y \) for every \((a, x, y)\), it is necessary and sufficient that the coefficients \((\varphi_0, \varphi_a, \varphi_x, \varphi_y)\) solve the following system:

\[
\begin{align*}
\varphi_0 &= \zeta + \Psi_0 \left\{ \varphi'_0 + (\varphi_a + \varphi_x) \left( \frac{\kappa_0}{\kappa_0 + \kappa_x + \kappa_y} \right) \mu \right\} \\
\varphi_a &= (1 - \Psi_0) \Psi_1 \\
\varphi_x &= \Psi_0 (\varphi_a + \varphi_x) \left( \frac{\kappa_x}{\kappa_0 + \kappa_x + \kappa_y} \right) \\
\varphi_y &= \Psi_0 \varphi_y + \Psi_0 (\varphi_a + \varphi_x) \left( \frac{\kappa_y}{\kappa_0 + \kappa_x + \kappa_y} \right)
\end{align*}
\]
Substituting \(\varphi_a\) into \(\varphi_x\) gives us:
\[
\varphi_x = \Psi_0 \left[ (1 - \Psi_0) \Psi_1 + \varphi_x \right] \left( \frac{\kappa_x}{\kappa_0 + \kappa_x + \kappa_y} \right) = \Psi_0 (1 - \Psi_0) \Psi_1 \left( \frac{\kappa_x}{(1 - \Psi_0) \kappa_0 + \kappa_x + \kappa_y} \right) = \left( \frac{(1 - \Psi_0) \kappa_x}{(1 - \Psi_0) \kappa_0 + \kappa_x + \kappa_y} \right) \Psi_0 \Psi_1.
\]

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Substituting $\varphi_a$ and $\varphi_x$ into $\varphi_y$ gives us:

$$\varphi_y = \Psi_0 \varphi_y + \Psi_1 \left[ (1 - \Psi_0) + \left( \frac{(1 - \Psi_0)\kappa_x}{(1 - \Psi_0)\kappa_x + \kappa_0 + \kappa_y} \right) \Psi_0 \Psi_1 \right] \left( \frac{\kappa_y}{\kappa_x + \kappa_0 + \kappa_y} \right)$$

$$= \Psi_0 \Psi_1 \left[ \frac{(1 - \Psi_0)\kappa_x + \kappa_0 + \kappa_y + \Psi_0\kappa_x}{(1 - \Psi_0)\kappa_x + \kappa_0 + \kappa_y + \Psi_0\kappa_x} \right] \left( \frac{\kappa_y}{\kappa_x + \kappa_0 + \kappa_y} \right)$$

$$= \Psi_0 \Psi_1 \left( \frac{\kappa_y}{(1 - \Psi_0)\kappa_x + \kappa_0 + \kappa_y} \right),$$

The expression for the final coefficient $\varphi_0$ comes from the elements in equation 55 that are not multiplied by $a$, $x$ or $y$. Therefore, the unique solution to this system for $(\varphi_a, \varphi_x, \varphi_y)$ is

$$\varphi_a = (1 - \Psi_0)\Psi_1$$

$$\varphi_x = \left\{ \frac{(1 - \Psi_0)\kappa_x}{(1 - \Psi_0)\kappa_x + \kappa_0 + \kappa_y} \right\} \Psi_0 \Psi_1$$

$$\varphi_y = \left\{ \frac{(1 - \Psi_0)\kappa_y}{(1 - \Psi_0)\kappa_y + \kappa_0 + \kappa_y} \right\} \Psi_0 \Psi_1$$

The coefficient $\varphi_0$ is uniquely determined from

$$\varphi_0 = \zeta + \Psi_0 \left\{ \varphi'_0 + (\varphi_a + \varphi_x) \frac{\kappa_0}{\kappa_0 + \kappa_x + \kappa_y} \mu \right\}$$

in combination with with the definitions for $(\zeta, \varphi'_0)$ and the expression for $Var[\log Q]$ in (52).

5.2.5 Information Dispersion and Strategic Complementarity

Proposition 4 gives us a closed-form solution for the equilibrium production strategy as a log-linear function of local productivity $a$, local private information $x$, and the public information released by the central bank $y$. The dispersion of information is relevant to the business cycle if and only if $\Psi_0 \neq 0$. When $\Psi_0 = 0$, local activity does not depend on expectations of aggregate activity:

$$\log Q_\omega = \varphi_0 + \Psi_1 a(\omega) \text{ and}$$

$$\log Q_\Omega = \varphi'_0 + \Psi_1 \bar{a}(\Omega).$$

When $\Psi_0 \neq 0$, $E[\log Q_\Omega | \omega]$ becomes important. The within-sector noise in local markets increases dispersion in employment levels between sectors, decreases the homogeneity of output between sectors and decreases relative prices. These
differences cannot be justified only by the idiosyncratic variations in local productivity levels. The level of precision in the information the central bank releases to the public, $\kappa_y$, contributes to aggregate fluctuations that are not connected to aggregate productivity.

The stronger the strategic complementarity ($\Psi_0$) the more the equilibrium level of output in any given island ($\log Q_\omega$) depends on local forecasts of aggregate output ($\mathbb{E}[\bar{a}]$) and the less it depends on current local fundamentals. This is because as $\Psi_0$ increases from 0 to 1, $\varphi_a = (1 - \Psi_0)\Psi_1$ decreases so that $a(\omega)$ has less of an impact on the equilibrium level of output. Additionally, as $\Psi_0$ increases, the values of $\varphi_0$ (which includes the expected value of $\bar{a}$), $\varphi_x$ and $\varphi_y$ become larger. These changes in the coefficients mean that the equilibrium output of each sector is influenced more by the expectations of $\bar{a}$, $x$ and $y$, and therefore by their respective signal precisions $\kappa_0$, $\kappa_x$ and $\kappa_y$. Local productivity $a(\omega)$ will have a relatively small part in the sectors’ expectations of $\log Q_\Omega$ and $\log Q_\omega$. Stronger complementarity induces firms and unions to rely more on common sources of information, making the central bank’s signal and the common prior relatively better predictions of others’ activity.

As more transparency induces the central bank to pay greater attention to its inflation target relative to its output gap, Jensen (2002) finds that the optimal degree of transparency often involves a tradeoff between credibility gains and flexibility losses. He assumes that inflation expectations are formed at the beginning of each period, which is what happens in the model examined in this section. An increase in transparency is therefore good if the credibility of the central bank’s inflation target is lacking. Additionally, an increase in stabilization leads to a reduction in the optimal level of transparency.

For any given $\Psi_1$, in terms of relative output,

$$\frac{\partial \varphi_x}{\partial \Psi_0} < 0 \quad \text{and} \quad \frac{\partial \varphi_y}{\partial \Psi_0} > 0.$$  

As the degree of strategic interaction increases, firms and unions base their expectations more on public information ($\varphi_y$) and less on private information ($\varphi_x$). This result is similar to the conclusions from James and Lawler’s model, in it is possible for an increase in transparency to lead to a decrease in public welfare. Private agents ignore parts of their information sets because they are paying more attention to public information and not enough attention to their private information. When strategic complementarity in decision making becomes stronger, these tendencies to weight private and public information differently in predictions of future output increase.

A final effect of note is that the stronger the strategic complementarity between sectors, the greater the noise-driven aggregate fluctuations and the smaller the technology-driven fluctuations. The anchoring effect to the prior explains why
aggregate output responds less than initially expected to innovation in technology, while the heightened sensitivity to noisy public information explains why aggregate output responds more to noise. Thus, for a given $\Psi_1$, in terms of aggregate output,

$$\frac{\partial \varphi_{\bar{a}}}{\partial \Psi_0} < 0 \quad \text{and} \quad \frac{\partial \varphi_{\eta}}{\partial \Psi_0} > 0$$

Finally, note that aggregate employment is given by

$$\log L(\Omega) = \text{const} + \frac{1}{\alpha} (\log Q_\Omega - \bar{a})$$

$$= \text{const} + \frac{1}{\alpha} [(\varphi_{\bar{a}} - 1)\bar{a} + \varphi_\tau \tau]$$

Therefore, increases in the magnitude and/or frequency of noise-driven fluctuations occur together with positive co-movements in employment, output and consumption, are not in a causal relationship with underlying productivity shocks, and are closely related to shifts in expectations about aggregate demand.

One of the main properties of this model’s equilibrium, that output levels respond more to public information than they do to private information, presents implications that mesh nicely with the findings of James and Lawler’s model. James and Lawler proposed, in their discussion about unions operating with monopolistic competition, that if the central bank and the unions place the same relative weight on employment stabilization, greater transparency is associated with more volatile employment and will result in losses for both the central bank and the private sector. If, as in Angeletos and La’O’s model, public information has a greater effect on output expectations than does private information, fluctuations in the central bank’s information releases would result in significant volatility in aggregate employment and output. This suggests that the central bank would be better off operating under a system in which it is required to keep the price level relatively stable. It could do this by refraining from operating under full transparency, as the actual shock level would not be apparent to the general public when it occurred, and so individual firms and unions would not drastically change their wage and employment demands.

Jensen (2010) comes to the same conclusion, finding that greater transparency on the part of the central bank leads to a more disciplined monetary policy. This is good if the bank lacks credibility, but bad if the bank authorities are frequently making adjustments for shocks which the public views as impermanent self-correcting.
6 Conclusion

Since the beginning of modern central banking, monetary authorities around the world have made great strides in opening up the inner workings of their financial toolboxes to the public. Although the concept of an opaque financial sector brings to mind unethical behavior and shady characters, it appears that releasing all information on central bank behavior immediately does not always increase economic efficiency and welfare. Examining how wage and employment demands change in the face of ever increasing amounts of information is important, since it is not likely for central banks to become less transparent in the foreseeable future. As more central banks switch to publishing their instruments' forecasts, the increase in available data will make it easier to examine what major effects, if any, highly transparent monetary authorities have on economic outcomes.
References


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