The Social Value of Information over the Business Cycle

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Abstract

What are the welfare effects of central-bank transparency or, more generally, enhanced dissemination of public information by the government or the media? We address this question within a micro-founded business-cycle model that is flexible enough to accommodate multiple shocks, either flexible or sticky prices, and various sources of information. Unlike what suggested by previous work, the degree of strategic complementarity featured in equilibrium is not central to answering the question of interest. Instead, what is central is the nature of the underlying shocks and the design of monetary policy. If the business cycle is driven by productivity or taste shocks and monetary policy is optimal, so that the “output gap” is constant, then more information necessarily raises welfare. If instead the business cycle is driven by shocks to monopoly mark-ups or other “wedges”, then more information typically decreases welfare.

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1 Introduction

Asset prices and economic activity often appear to react with heightened sensitivity to news disseminated by the media or to disclosures of information by the central bank and other government agencies. Judged on the basis of their informativeness about the underlying economic fundamentals, the market’s reaction to such news often feels “excessive”. While it is hard to quantify it, a simple logic underlies this feeling. Market participants are likely to have access to multiple sources of information—or signals—about the underlying fundamentals, including the signals revealed through markets and other forms of social interaction. In a typical representative-agent macro model, one would expect the agent(s) to weight the various signals in proportion to their informativeness, putting less weight on any given signal the less precise that signal is or the higher the number and precision of other available signals. If the aforementioned public news are only a few of the many signals, and are rather noisy, the response of the economy to these news is predicted to be weak. But this seems hard to reconcile with the sensitivity observed in real-world markets.

These observations raise an important normative question regarding the social value of public information. Does the provision of more precise public information—e.g., through the speedy publication of more accurate economic statistics or through increased transparency in central-bank decisions—raise welfare? Or could it perhaps reduce welfare due to the aforementioned “excessive” reaction of the markets to such information?

This paper is concerned about answering this question within the context of business cycles. In so doing, we build upon an influential paper by Morris and Shin (2002), which showed that the social value of information could be negative within a particular game that was meant to formalize Keynes’ beauty contest; a sequel by Angeletos and Pavan (2007), which studied the social value of information within a broader class of games; and other work that has followed Morris and Shin and have largely interpreted their result as a case against central-bank transparency.

We differentiate from this previous work by addressing the question of interest with a fully micro-founded business-cycle model, rather than an abstract class of games where, at least in principle, “anything goes”.¹ Our model is tractable enough to facilitate a clear theoretical investigation, and yet rich enough to capture a number of features that have been central to business-cycle theory.

¹This, however, does not mean that there is no structure on “what goes when”. It only means that the presence of strategic complementarity alone does not put any restrictions on the social value of information. Indeed, there is a class of games that share exactly the same best responses, and hence exactly the same equilibrium behavior, as the game studied in Morris and Shin (2002) but have very different implications for the social value of information. See Angeletos and Pavan (2007) and the discussion in the next section.
More specifically, we let the economy be hit by multiple shocks, such as shocks to technologies and preferences, as well as shocks to monopoly power or other “wedges”. We further allow nominal prices to be either flexible (as in the RBC paradigm) or sticky (as in the New-Keynesian paradigm). Finally, we let agents observe, not only exogenous signals about the underlying shocks, but also endogenous signals about economic activity, such as statistics of aggregate output and employment.

The empirical relevance of the first two features (multiple shocks and flexible-vs-sticky prices) is self-evident; but the third feature (endogenous signals) is also important. Most of the signals disseminated by the media or government agencies are about economic activity, not about the shocks typically featured in a macro model. In fact, the notions of “exogenous shocks” or “fundamentals” are only constructs of the model, often without obvious counterparts in the real world. Our framework permits us to interpret an improvement in public information either as a reduction in the noise of an exogenous public signal of the underlying shocks or, more realistically, as a reduction of the measurement error in the available statistics of aggregate economic activity.

Our investigation of the social value of information leads to a very different lesson than the one associated with Morris and Shin (2002). As in that paper, the strength of strategic complementarity in our model—once appropriately identified—plays a crucial role in determining the positive properties of the equilibrium: stronger complementarity may amplify the response of the economy to noisy public news, thus formalizing a sense in which this reaction may look “excessive” to an outside observer. However, unlike that paper, the complementarity plays no essential role in determining the normative properties of the economy. Rather, the main lesson of our paper regarding the question of interest can be summarized as follows.

**Main lesson.** The welfare effects of public information are determined, first and foremost, by the nature of the shocks hitting the economy and, to a lesser extent, by the design of monetary policy.

Let us elaborate on this. Consider first a benchmark case where the business cycle is driven *only* by productivity or taste shocks, not by shocks to monopoly power or other “wedges”. Suppose further either that nominal prices are flexible or that monetary policy replicates flexible-price allocations, which is actually the optimal thing to do in this benchmark case. Depending on preference and technology parameters, firm decisions may feature an arbitrarily large degree of strategic complementarity, thus sharing some of the features associated with a Keynesian beauty contest. Yet, the social value of public information is unambiguously positive: an increase in the precision of public information *increases* equilibrium welfare, no matter how “excessive” the

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2 For example, one would have hard time finding in the market place or the public media any discussions regarding either the Solow residual or the shocks identified in most SVARs!
response of the economy to that information may look like.

Next, consider another special case, one where the business cycle is driven only by shocks to monopoly mark-ups or other “wedges”. Continue to assume that prices are flexible or that monetary policy replicates flexible-price allocations. In this case, we find that more precise public information is likely to decrease welfare. In particular, we find that this is the case if and only if the average “output gap” between the equilibrium and the first-best allocation is not too high.³

Finally, consider the general case where the business cycle is driven by both types of shocks. In this case, the analysis is more complicated, and the design of monetary policy plays a non-trivial role. However, as long as monetary policy is optimal, then the core message of the aforementioned two special cases survives: the social value of public information tends to be positive if the business cycle is driven mostly by productivity or taste shocks, and negative if it is driven mostly by shocks to monopoly mark-ups or other wedges.

These results can be understood as follows. Consider first the benchmark case. When the economy is hit only by productivity or taste shocks, the flexible-price business cycle is constrained efficient in the sense that the response of the equilibrium to the underlying shocks, or to any information about them, coincides with those of the social planner’s solution.⁴ Because the planner cannot be worse off with more information (he always have the option to “ignore” the additional information), it follows that equilibrium welfare necessarily increases with more public information. Importantly, note that the equilibrium may well feature an inefficiently low mean level of activity, because of monopolistic distortions or other wedge, and in this sense equilibrium allocations do not fully coincide with efficient allocations. However, the key for the aforementioned result is whether a certain distance between the equilibrium and the efficient allocations is invariant with the business cycle: if this “gap” is acyclical, then more information is necessarily welfare improving.

Turning to cases where this gap is variable, the precise intuitions are more convoluted. We thus have to postpone a proper discussion for later on. Nevertheless, it is worth highlighting two insights. First, if monetary policy has real effects and happens to respond suboptimally to the shocks hitting the economy, then this can open the door to a negative social value for information even in the case of otherwise efficient business cycles—but it is then only the suboptimality of policy

³This condition is trivially satisfied when the government can use a simple, non-contingent subsidy to eliminate the average output gap. While this subsidy is often taken for granted in many New-Keynesian models in order to simplify welfare analysis, we do not wish to take a stand on its feasibility. We thus allow for the more general case.

⁴That the flexible-price business cycle is efficient in the absence of shocks to monopoly power or other “wedges” is well known in the literature (e.g., Woodford, 2003b), although only under the assumption of common information. That this property extends to heterogeneous information, which is the case of interest here, was first established in Angeletos and La’O (2008, 2009).
that could justify less information or less central-bank transparency. Second, when the economy is hit only by shocks to mark-up or other wedges, then the entire business cycle is inefficient even if monetary policy is optimal (or simply irrelevant). A reduction in the precision of available public information may then help reduce volatility at the aggregate level, but possibly at the expense of higher variation at the cross section; this is because less precise public information induces agents to respond more to their private sources of information. Because both types of variability are socially undesirable, the overall welfare effect is ambiguous in general. Our key result then is that, as long as the average efficient gap is not too large, less information can increase welfare—and, by implication, “constructive ambiguity” may then be desirable.

The rest of the paper is organized as follows. Section 2 reviews some of the related literature in order to help calibrate the contribution of our paper and also to highlight what, in our view, is a certain confusion in the current state of the art. Section 3 introduces the baseline model, which abstracts from nominal frictions and monetary policy. Section 4 analyzes the social value of information for this baseline model. Section 5 extends the analysis to a setting with sticky prices, thus shedding light on the role of monetary policy. Section 6 concludes.

2 A brief, biased, review of the literature

As already mentioned, the welfare effects of public information was the subject of a highly influential paper Stephen Morris and Hung Son Shin (2002). That paper considered an abstract game in which best responses took the following form:

\[ a_i = (1 - r)\bar{E}[\theta] + r\bar{E}[\bar{a}] \]  

(1)

where \( a_i \) denotes the action of player \( i \), \( E_i \) denotes his expectation, \( \theta \) denotes an exogenous payoff-relevant random variable (meant to capture the exogenous economic fundamentals), \( \bar{a} \) is the average action in the population, and \( r \in (0, 1) \) is an exogenous scalar that measures the degree of strategic complementarity. The key result of the paper was then that an increase in the precision of public information could reduce welfare when \( r \) was sufficiently high.

The aforementioned best responses were astonishingly similar to a key condition of the standard New-Keynesian paradigm: if one interprets \( a_i \) as the nominal price set by a firm, \( \theta \) as aggregate nominal demand, and \( \bar{p} \) as the average price level, then condition (1) coincides with the condition

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5 The impact of this paper can be quantified as follows. As of February 2010, there were 479 citations in Google Scholar. Moreover, the paper was among the top 0.1% most cited papers in IDEAS, once discounted by age and weighted by either simple or recursive impact factors. Finally, the paper also got the attention of the general public, through media coverage, and central bankers.
that characterizes the optimal target price in a typical New-Keynesian model (e.g., Gali, 2003; Woodford, 2003). Furthermore, Morris and Shin appear to have favored a potential business-cycle interpretation of their results by eluding to the resemblance between their model and the island-economy models of Phelps (1970) and Lucas (1972, 1973), and by discussing the potential implications of their results for the desirability central-bank transparency.

This probably explains why many have mis-interpreted the result of Morris and Shin as directly applicable to business cycles, despite the fact that their model was abstract and, most crucially, that the assumption that drove their result—namely that the coordination motive was socially undesirable—need not hold in a business-cycle context. In this paper we hope to resolve this confusion by thoroughly investigating the social value of information within a canonical, micro-founded, business-cycle model.

Closely related in this respect are Hellwig (2006) and Mauro (2006). These papers considered a New-Keynesian business-cycle model, assumed that monetary supply was an exogenous random variable, and focused on the welfare effects of more precise information about it. In contrast, we consider different type of shocks—namely shocks to technologies, preferences, and wedges—and let monetary policy to be optimally designed. We believe that this makes our approach a priori more appealing. Most importantly, the main lesson of our paper, regarding the central role of the nature of the shocks for the question of interest, cannot be found in this prior work—simply because this prior work did not consider this important dimension.

Another novelty in our approach is the introduction of endogenous statistics about economic activity. As already mentioned, we believe that this is important for the applicability of the analysis to a business-cycle context. In this respect, we complement Amador and Weill (2008, 2009), which have also considered certain welfare implications of such endogenous statistics, although focusing on a different issue, namely the inefficiencies induced by informational externalities.

The methodological underpinnings of our investigation are partly guided by Angeletos and Pavan (2007), which highlighted that the key to understanding the welfare effects of information is, not the presence of strategic complementarity or absence thereof, but rather the relation between the equilibrium and the efficient use of information. However, that paper did not consider a business-cycle context.

Finally, the paper compliments a large number of papers that have followed the initial contribution of Morris and Shin, including Amato and Shin (2006), Heinemann and Cornand (2004), Svensson (2005), ....

[to be completed]
3 The model

3.1 Set-up

The basic model is the same as in Angeletos and La’O (2009). There is a (unit-measure) continuum of households, or “families”, each consisting of a consumer and a continuum of workers. There is a continuum of “islands”, which define the boundaries of local labor markets as well as the “geography” of information: information is symmetric within an island, but asymmetric across islands. Each island is inhabited by a continuum of firms, which specialize in the production of differentiated commodities. Households are indexed by \( h \in H = [0,1] \); islands by \( i \in I = [0,1] \); firms and commodities by \((i,j) \in I \times J\); and periods by \( t \in \{0,1,2,\ldots\} \).

Each period has two stages. In stage 1, each household sends a worker to each of the islands. Local labor markets then open, workers decide how much labor to supply, firms decide how much labor to demand, and local wages adjust so as to clear the local labor market. At this point, workers and firms in each island have perfect information regarding local productivity, but imperfect information regarding the productivities in other islands. After employment and production choices are sunk, workers return home and the economy transits to stage 2. At this point, all information that was previously dispersed becomes publicly known, and commodity markets open. Quantities are now pre-determined by the exogenous productivities and the endogenous employment choices made during stage 1, but prices adjust so as to clear product markets.

**Households.** The utility of household \( h \) is given by

\[
u_h = \sum_{t=0}^{\infty} \beta^t \left[ U(C_{h,t}) - \int_I S_{i,t}^n V(n_{hi,t}) di \right]
\]

with

\[
U(C) = \frac{C^{1-\gamma}}{1-\gamma} \quad \text{and} \quad V(n) = \frac{n^{1+\epsilon}}{1+\epsilon}.
\]

Here, \( \gamma \geq 0 \) parametrizes the income elasticity of labor supply, \( \epsilon \geq 0 \) parameterizes the Frisch elasticity of labor supply, \( n_{hi,t} \) is the labor of the worker who gets located on island \( i \) during stage 1 of period \( t \), \( S_{h,t}^n \) is an island-specific shock to the disutility of labor, and \( C_{h,t} \) is a composite of all the commodities that the household purchases and consumes during stage 2.

This composite, which also defines the numeraire used for wages and commodity prices, is given by the following nested CES structure:

\[
C_{h,t} = \left[ \int_I S_{i,t}^{\gamma} c_{hi,t}^{\frac{\gamma-1}{\gamma}} di \right]^{\frac{\gamma}{\gamma-1}}
\]

Note that risk aversion and intertemporal substitution play no role in our setting because all idiosyncratic risk is insurable and there is no capital. Therefore, \( \gamma \) only controls the sensitivity of labor supply to income for given wage.
where

\[ c_{hi,t} = \left[ \int J \frac{\eta_{jt}}{c_{hi,jt}} \, dj \right]^{\frac{\eta_{jt}}{\eta_{jt} - 1}} \]

and where \( c_{hi,jt} \) is the quantity household \( h \) consumes in period \( t \) of the commodity produced by firm \( j \) on island \( i \). \( S^c_{i,t} \) is an island-specific shock to the utility of the goods produced by island \( i \). Here, \( \eta_{jt} \) is a random variable that determines the period-\( t \) elasticity of demand faced by any individual firm within a given island \( i \), while \( \rho \) is the elasticity of substitution across different islands. Letting the within-island elasticity \( \eta \) differ from the across-islands elasticity \( \rho \) permits us to distinguish the degree of monopoly power (which will be determined by the former) from the strength of trade linkages and the associated degree of strategic complementarity (which will be determined by the latter).

Households own equal shares of all firms in the economy. The budget constraint of household \( h \) is thus given by the following:

\[
\int J x_i \ p_{ij,t} c_{hi,jt} d(j,k) + B_{h,t+1} \leq \int J x_i \ \pi_{ij,t} d(i,j) + \int I w_{it} n_{hi,t} dk + R_t B_{h,t},
\]

where \( p_{ij,t} \) is the period-\( t \) price of the commodity produced by firm \( j \) on island \( i \), \( \pi_{ij,t} \) is the period-\( t \) profit of that firm, \( w_{it} \) is the period-\( t \) wage on island \( i \), \( R_t \) is the period-\( t \) nominal gross rate of return on the riskless bond, and \( B_{h,t} \) is the amount of bonds held in period \( t \).

The objective of each household is simply to maximize expected utility subject to the budget and informational constraints faced by its members. Here, one should think of the worker-members of each family as solving a team problem: they share the same objective (family utility) but have different information sets when making their labor-supply choices. Formally, the household sends off during stage 1 its workers to different islands with bidding instructions on how to supply labor as a function of (i) the information that will be available to them at that stage and (ii) the wage that will prevail in their local labor market. In stage 2, the consumer-member collects all the income that the worker-member has collected and decides how much to consume in each of the commodities and how much to save (or borrow) in the riskless bond.

**Asset markets.** Asset markets operate in stage 2, along with commodity markets, when all information is commonly shared. This guarantees that asset prices do not convey any information. The sole role of the bond market in the model is then to price the risk-free rate. Moreover, because our economy admits a representative consumer, allowing households to trade risky assets in stage 2 would not affect any of the results.

**Firms.** The output of firm \( j \) on island \( i \) during period \( t \) is given by

\[ q_{ij,t} = A_{i,t} (n_{ij,t})^\theta \]
where \( A_{i,t} \) is the productivity in island \( i \), \( n_{ij,t} \) is the firm’s employment, and \( \theta \in (0, 1) \) parameterizes the degree of diminishing returns in production. The firm’s realized profit is given by

\[
\pi_{ij,t} = p_{ij,t}q_{ij,t} - w_{i,t}n_{ij,t}
\]

Finally, the objective of the firm is to maximize its expectation of the representative consumer’s valuation of its profit, namely, its expectation of \( U'(C_t)\pi_{ij,t} \).

**Labor and product markets.** Labor markets operate in stage 1, while product markets operate in stage 2. Because labor cannot move across islands, the clearing conditions for labor markets are as follows:

\[
\int_J n_{ij,t}dj = \int_H n_{hi,t}dh \forall i
\]

On the other hand, because commodities are traded beyond the geographical boundaries of islands, the clearing conditions for the product markets are as follows:

\[
\int_H c_{hi,j}dh = q_{ij,t} \forall (i,j)
\]

**Fundamentals and information.** Each island in our economy is subject to four types of shocks: shocks to the technology used by local firms (TFP shocks); shocks to the disutility of labor faced by local workers (labor taste shocks); shock to the utility of locally produced goods (consumption taste shocks); and shocks to the elasticity of demand faced by local firms, which cause variation in their monopoly power (mark-up shocks). We allow for both aggregate and idiosyncratic components to these shocks.

The aggregate fundamentals of the economy in period \( t \) are identified by the joint distribution of the shocks \( (A_{it}, S_{it}^o, S_{it}^c, \eta_{it}) \) in the cross-section of islands.\(^7\) Let \( \Psi_t \) denote this distribution. We assume that different islands observe only noisy private (local) signals about \( \Psi_t \) in stage 1, when they have to make their decentralized employment and production choices. On the other hand, we assume that \( \Psi_t \) becomes common known in stage 2, when agents meet in the centralized commodity and financial markets. We will make different assumptions about the signals observed by firms and workers.

### 3.2 Equilibrium

In this section we characterize the equilibrium by providing a game-theoretic representation that turns out to be instrumental for our subsequent analysis.

\(^7\)In special cases (as with Assumption 1 later on), this distribution might be conveniently parameterized by the mean values of the shocks; but in general the aggregate fundamentals are identified by the entire distribution.
3.2.1 Definition

Because each family sends workers to every island and receives profits from every firm in the economy, each family’s income is fully diversified during stage 2. This guarantees that our model admits a representative consumer and that no trading takes place in the financial market. To simplify the exposition, we thus set $B_t = 0$ and abstract from the financial market. Furthermore, because of the symmetry of preferences, technologies and information within each island, it is without any loss of generality to impose symmetry in the choices of workers and firms within each island.

**Definition 1.** An equilibrium consists of an employment strategy $n_{it}$, a production strategy $q_{it}$, a wage function $w_{it}$, an aggregate output function $Q_t$, an aggregate employment function $N_t$, a price function $p_{it}$, and a consumption strategy $c: \mathbb{R}_+^3 \to \mathbb{R}_+$, such that the following are true:

(i) The price function is normalized so that

$$P_t = \left[ \int p_{it}^{1-\rho} \, di \right]^{\frac{1}{1-\rho}} = 1$$

for all $t$.

(ii) The quantity $c(p, p', Q)$ is the representative consumer’s optimal demand for any commodity whose price is $p$ when the price of all other commodities from the same island is $p'$ and the aggregate output (income) is $Q$.

(iii) $p_{it}$ is the price that clears the market for the product of the typical firm on island $i$; the employment and output levels of that firm are, respectively, $n_{it}$ and $q_{it}$, with $q_{it} = A_{it} n_{it}^\rho$; and the aggregate output and employment indices are, respectively,

$$Q_t = \left\{ \int q_{it}^{\rho-1} \, di \right\}^{\frac{\rho}{\rho-1}} \quad \text{and} \quad N_t = \int n_{it} \, di.$$

(iv) The quantities $n_{it}$ and $q_{it}$ are optimal from the perspective of the typical firm in island $i$, taking into account that firms in other islands are behaving according to the same strategies, that the local wage is given by $w_{it}$, that prices will be determined in stage 2 so as to clear all product markets, that the representative consumer will behave according to consumption strategy $c$, and that aggregate income will be given by $Q_t$.

(v) The local wage $w_{it}$ is such that the quantity $n_{it}$ is also the optimal labor supply of the typical worker in an island $i$.

Note that condition (i) simply means that the numeraire for our economy is the CES composite defined when we introduced preferences. The rest of the conditions then represent a hybrid of
a Walrasian equilibrium for the complete-information exchange economy that obtains in stage 2, once production choices are fixed, and a subgame-perfect equilibrium for the incomplete-information game played among different islands in stage 1.

Let us expand on what we mean by this. When firms in an island decide how much labor to employ and how much to produce during stage 1, they face uncertainty about the prices at which they will sell their product during stage 2 and hence they face uncertainty about the marginal return to labor. Similarly, when workers in an island decide how much labor to supply, they face uncertainty about the real income their household will have in stage 2 and hence face uncertainty about the marginal value of the wealth that they can generate by working more. But then note that firms and workers in each island can anticipate that the prices that clear the commodity markets and the realized level of real income are, in equilibrium, determined by the level of employment and production in other islands. This suggests that we can solve for the general equilibrium of the economy by reducing it to a certain game, where the incentives of firms and workers in an island depend on their expectations of the choices of firms and workers in other islands. We implement this solution strategy in the following.

3.2.2 Characterization

Towards solving for the equilibrium, consider first how the economy behaves in stage 2. The optimal demand of the representative consumer for a commodity from island $i$ whose price is $p_{it}$ when the price of other commodities in the same island is $p_{0it}$ is given by the following:

$$c_{it} = \left(\frac{p_{it}}{p_{0it}}\right)^{-\eta t} \left(\frac{p_{0it}}{P_t}\right)^{-\rho} C_t,$$

where $P_t = 1$ by our choice of numeraire.\(^8\) In equilibrium, $C_t = Q_t$. It follows that the equilibrium consumption strategy is given by $c(p, p', Q) = p^{-\eta} (p')^{\eta - \rho} Q$. Equivalently, the inverse demand function faced by a firm during period $t$ is

$$p_{it} = (p'_{it})^{1-\frac{\rho}{\eta t}} q_{it}^{\frac{1}{\eta t}} Q_t^{\frac{1}{\eta t}} \quad (2)$$

Consider now stage 1. Given that the marginal value of nominal income for the representative household is $U'(C_t)$ and that $C_t = Q_t$ in equilibrium, the objective of the firm is simply

$$\mathbb{E}_{it} \left[ U' (Q_t) (p_{it} q_{it} - w_{it} n_{it}) \right].$$

\(^8\)To understand this condition, note that $c_{it} = \left(\frac{p_{it}}{p_{0it}}\right)^{-\eta} C_t$ is the demand for the basket of commodities produced by a particular island; the demand for the commodity of a particular firm in that island is then $c_{it} = \left(\frac{p_{it}}{P_t}\right)^{-\eta} c_{it}$.\(^8\)
Using (2), we conclude the typical firm on island $\omega_t$ maximizes the following objective:

$$E_{it} \left[ U'(Q_t) \left( \left( p'_{it} \right)^{1 - \theta} q_{it}^{\frac{1}{\eta_{it}}} \right)^{-\theta} \left( 1 - \frac{1}{\eta_{it}} \right) - w_{it} n_{it} \right],$$

(3)

where $q_{it} = A_{it} n_{it}^\theta$. As long as $1 > (1 - \frac{1}{\eta}) \theta > 0$ (which we assume to be always the case), the above objective is a strictly concave function of $n_{it}$, which guarantees that the solution to the firm’s problem is unique and that the corresponding first-order condition is both necessary and sufficient. This condition is simply given by equating the expected marginal cost and revenue of labor, evaluated under local expectation of the equilibrium pricing kernel:

$$E_{it} \left[ U'(Q_{it}) \right] w_{it} = \left( \frac{n_{it} - 1}{\eta_{it}} \right) E_{it} \left[ U'(Q_t) \left( p'_{it} \right)^{1 - \theta} \left( q_{it}^{\frac{1}{\eta_{it}}} \right)^{-\theta} \right] \left( \theta A_{it} n_{it}^{\theta - 1} \right).$$

(4)

Next, note that, since all firms within an island set the same price in equilibrium, it must be that $p'_{it} = p_{it}$. Along with (2), this gives

$$p'_{it} = p_{it} = \left( \frac{q_{it}}{Q_t} \right)^{-\frac{1}{\rho}}.$$

(5)

This simply states that the equilibrium price of the typical commodity of an island relative to the numeraire is equal to the MRS between that commodity and the numeraire. Finally, note that the optimal labor supply of the typical worker on island $i$ is given by equating the local wage with the MRS between the numeraire and leisure:

$$w_{it} = \frac{S_{it} n_{it}^{\rho - 1}}{E_{it} \left[ U'(Q_{it}) \right]}.$$

(6)

Conditions (5) and (6) give the equilibrium prices and wages as functions of the equilibrium allocation. Using these conditions into condition (4), we conclude that the equilibrium allocation is pinned down by the following condition:

$$S_{it} n_{it}^{\rho - 1} = \left( \frac{n_{it} - 1}{\eta_{it}} \right) E_{it} \left[ U'(Q_t) \left( q_{it}^{\frac{1}{\eta_{it}}} \right)^{-\theta} \right] \left( \theta A_{it} n_{it}^{\theta - 1} \right).$$

(7)

This condition has a simple interpretation: it equates the private cost and benefit of effort in each island. To see this, note that the left-hand side is simply the marginal disutility of an extra unit of labor in island $i$; as for the right-hand side, $\frac{n_{it} - 1}{\eta_{it}}$ is the reciprocal of the local monopolistic mark-up, $U'(Q_t) \left( \frac{q_{it}}{Q_t} \right)^{-\frac{1}{\rho}}$ is the marginal utility of an extra unit of the typical local commodity, and $\theta A_{it} n_{it}^{\theta - 1}$ is the corresponding marginal product of labor.

Note that condition (7) expresses the equilibrium levels of local employment $n_{it}$ and local output $q_{it}$ in relation to the local shocks and the local expectations of aggregate output $Q_t$. Using the
production function, $q_{it} = A_{it}n_{it}^{\theta}$, to eliminate $n_{it}$ in this condition, and reverting to the more precise notation of Definition 1 (i.e., replacing $q_{it}$ with $q(\omega_t, \Omega_{t-1})$, $Q_t$ with $Q(\Omega_t, \Omega_{t-1})$, $A_{it}$ with $A(\omega_t)$, and so on), we reach the following result.

**Proposition 1.** Let

$$f_{it} \equiv \log \left\{ \theta^{\frac{\theta}{1-\rho+\gamma}} \left( \eta_{it} - 1 \right)^{\frac{\theta}{1-\rho+\gamma}} (S_{it}^{n_{it}})^{-\frac{\theta}{1-\rho+\gamma}} A_{it}^{\frac{1+\gamma}{1-\rho+\gamma}} \right\}$$

be a composite of all the local shocks hitting an island of type $\omega$ and define the coefficient

$$\alpha \equiv \frac{\frac{1}{\rho} - \gamma}{\frac{1}{\sigma} + \frac{1}{\rho} - 1} < 1$$

The equilibrium levels of local and aggregate output are the solution to the following fixed-point problem:

$$\log q_{it} = (1 - \alpha) f_{it} + \alpha \log \left\{ \mathbb{E}_{it} \left[ Q_{t}^{\frac{1}{\rho-\gamma}} \right]^{\frac{1}{\rho - \gamma}} \right\} \quad \forall i, t$$

(8)

$$Q_t = \left[ \int q_{it}^{\frac{1}{\rho-1}} di \right]^{\frac{\rho}{\rho-1}} \quad \forall i, t.$$  

(9)

This result establishes that the general equilibrium of our economy reduces to a simple fixed-point relation between local and aggregate output. In so doing, it offers a game-theoretic representation of our economy, similar to the one established in Angeletos and La’O (2009b) for a variant economy with capital. To see this, consider a game with a large number of players, each choosing an action in $\mathbb{R}_+$. Identify a “player” in this game with an island in our economy and interpret the level of output of that island as the “action” of the corresponding player. Next, identify the “types” of these players with the information they have, which includes local shocks and local information sets in our economy. Finally, let their “best responses” be given by condition (8). It is then evident that the Perfect Bayesian equilibrium of this game identifies the general equilibrium of our economy.

Note then that the variable $f_{it}$ conveniently summarizes all the local economic fundamentals, while the coefficient $\alpha$ identifies the degree of strategic complementarity in our economy. To see this more clearly, consider a log-linear approximation to conditions (8) and (9):

$$\log q_{it} = \text{const} + (1 - \alpha) f_{it} + \alpha \mathbb{E}_{it} [\log Q_t],$$

(10)

$$\log Q_t = \text{const} + \int \log q_{it} di,$$

(11)
where \(\text{const}\) capture second- and higher-order terms.\(^9\) It is then evident that the coefficient \(\alpha\) identifies the slope of an island’s best response to the activity of other islands—which is the standard definition of the degree of strategic complementarity.

To determine whether more information is beneficial for the representative household we need to consider the different shocks separately. It turns out that a useful way to classify the four shocks that we are considering in this paper (productivity, consumption taste shock, leisure taste shock, and markup shock) is to group them together depending on whether they would generate an efficient or inefficient business cycle when there is complete information in the economy.

4 Social Value of Information

In this section we are going to analyze the social value of better information for our baseline model. We will first consider productivity (and taste) shocks and markup shocks separately. Finally, we will combine the two shocks together.

4.1 Productivity and Taste shocks

Consider first the case where productivity and taste shocks drive the business cycle, and assume that the local markups are constant and equal to \(\bar{\mu}\). In this environment it is well known that if information was complete, then it would be efficient to eliminate the constant markup (output is inefficiently low) and leave the business cycle fluctuations unaffected. In other words, even if the level of activity is too low, under complete information the social planner finds that the business cycle is efficient.

For expositional simplicity we are going to treat exogenous and endogenous information separately.

4.1.1 Exogenous Information

The shocks and the available information satisfy the following properties.

First, the aggregate fundamental shock \(\bar{a}_t\) follows a Gaussian AR(1) or random walk process:

\[
\bar{a}_t = \psi \bar{a}_{t-1} + \nu_t, \tag{12}
\]

\(^9\)In general, these second- and higher-order terms may depend on the underlying state and the above is only an approximation. However, when the underlying shocks and signals are jointly log-normal with fixed second moments (as imposed by Assumption 1 in the next section), these terms are invariant, the approximation error vanishes, and conditions (10) and (11) are exact.
where $\psi$ parameterizes the persistence of the composite shock and $\nu_t$ is a Normal innovation, with mean 0 and variance $\sigma^2_\nu = \frac{1}{\kappa_f}$, i.i.d. over time.

Second, the local fundamental shock $a_t$ is given by

$$a_{it} = \bar{a}_t + \xi_{it}, \quad (13)$$

where $\xi_{it}$ is a purely idiosyncratic shock, Normally distributed with mean 0 and variance $\sigma^2_\xi$, orthogonal to $\bar{a}_t$, and i.i.d. across islands. Note that the local fundamental $a_{it}$ is itself a private signal of $\bar{a}_t$.\(^\text{10}\)

Every agent has also access to public information about the aggregate shock $\bar{a}_t$ captured by a Gaussian signal $y_t$ such that

$$y_t = \bar{a}_t + \varepsilon_t, \quad (14)$$

where $\varepsilon_t$ is noise, Normally distributed with mean 0 and variance $\sigma^2_\varepsilon = \frac{1}{\kappa_y}$, and orthogonal to all other variables.

Letting

$$\beta_a \equiv \frac{\frac{1+\alpha}{\alpha}}{\frac{1+\alpha}{\gamma} + \gamma - 1},$$

we can use (12), (13), and (14) to solve the functional equation (8) in closed-form.

**Lemma 1.** When shocks and information are given by (12), (13), and (14), the solution to (8) is given by

$$\log q_{it} = \varphi_0 + \varphi_a a_{it} + \varphi_y y_t$$

where

$$\varphi_0 = (1 - \alpha) \beta_a, \quad \varphi_a = \left\{ \frac{(1 - \alpha) \kappa_x}{(1 - \alpha) \kappa_x + \kappa_y + \kappa_0} \right\} \beta_a, \quad \varphi_y = \left\{ \frac{\kappa_y}{(1 - \alpha) \kappa_x + \kappa_y + \kappa_0} \right\} \alpha \beta_a$$

The next proposition is the main result of this section. It states that when information is exogenous and economic fluctuations are driven by productivity or taste shocks, then more public information always improves welfare.

**Proposition 2.** Let $W(\kappa_y)$ denote equilibrium welfare as a function of the precision of the public signal, then

$$\frac{\partial W(\kappa_y)}{\partial \kappa_y} > 0$$

\(^\text{10}\)Note that the local fundamental $f_{it}$ is itself a private signal of $f_t$. However, by the fact that we define $x_{it}$ as a sufficient statistic of all the local private information, the informational content of $f_{it}$ is already included in $x_{it}$.
In the appendix we prove proposition 2 by simply plugging the equilibrium quantities in lemma 1 into the welfare function and differentiating it. Here, we provide some intuition for this result. Remember that in information theory Blackwell’s theorem states that in a single agent decision problem more information can never harm the agent. The reason is that the agent can always disregard the new information when taking her decision.

Now, our problem would be isomorphic to a single agent decision problem, the single agent being the social planner, if we proved that the equilibrium under dispersed information is efficient. The appropriate notion of constrained efficiency in this environment is similar to the one used by Angeletos and Pavan (2007, 2008) in a more abstract framework, here adapted to our business-cycle economy. According to this notion of efficiency, the planner can dictate the allocations that the agents choose, but cannot alter the geographical segmentation of information.

In a very similar model, Angeletos and La’O (2009) prove that if the business cycle is driven by productivity or taste shocks and information is exogenous, then the equilibrium is efficient. The only difference in the model we consider in this paper is that firms have monopoly power and thus the equilibrium is inefficient also under complete information. Therefore, we cannot simply invoke Blackwell’s theorem to prove our result.

Nonetheless, lemma 1 shows that the conclusion of Blackwell’s theorem still holds in our setting. A positive, but constant markup affects the level of economic activity, not the use of information; hence, more public information improves welfare.

### 4.1.2 Endogenous Information

Things become more complicated when we allow for endogenous information. As first shown by Amador and Weill (2006, 2008) in a more abstract setting, when information is endogenous agents typically don’t take into account how the way they use information affects the information of other agents. Due to these informational externalities, agents put too little weight on their private information and the equilibrium is not constrained efficient anymore. It is possible to prove, however, that also with endogenous information welfare increases when public information is made more precise.

In what follows, we assume that the only public information available to the agents is a signal about the level of aggregate economic activity\(^{11}\). Formally, we replace \(y_t\) in assumption 2 with the following endogenous signal:

\[
y_t^q = \log Q_t + \tilde{\xi}_t, \quad \tilde{\xi}_t \sim N(0, 1/\kappa_y)
\]  

\(^{11}\)The results would not change if instead we considered a statistic about aggregate employment.
In the appendix we show that in equilibrium it is possible to rewrite (15) as an exogenous signal

\[ y_t = \tilde{a}_t + \varepsilon_t, \quad \varepsilon_t \sim N \left(0, 1/\kappa_y\right) \]

where \( \kappa_y \) is a fixed point of \( \kappa_y = (\varphi_a + \varphi_x(\kappa_y))^2 \tilde{\kappa}_y \). This transformation allows us to prove an equivalent version of lemma 1 for the case with endogenous information.

**Lemma 2.** Under assumption (12), (13), and (15), we have that

(i) In equilibrium \( y_t^q \) can be rewritten as

\[ y_t = a_t + \varepsilon_t, \quad \varepsilon_t \sim N \left(0, 1/\kappa_y^2\right) \]

where \( \kappa_y \) is a fixed point of \( \kappa_y = (\varphi_a + \varphi_x(\kappa_y))^2 \tilde{\kappa}_y \).

(ii) The solution to (8) is given by

\[ \log q_{i,t} = \varphi_0 + \varphi_a a_{it} + \varphi_y y_t \]

where

\[
\varphi_0 = (1 - \alpha) \beta_a, \quad \varphi_a = \left(\frac{(1 - \alpha) \kappa_x}{(1 - \alpha) \kappa_x + \kappa_y + \kappa_0}\right) \beta_a, \quad \varphi_y = \left(\frac{\kappa_y}{(1 - \alpha) \kappa_x + \kappa_y + \kappa_0}\right) \alpha \beta_a
\]

The next proposition extends the conclusion of proposition 2 to the case of endogenous information.

**Proposition 3.** Let \( W(\tilde{\kappa}_y) \) be equilibrium welfare as a function of the precision of the endogenous public signal, then

\[ \frac{\partial W(\tilde{\kappa}_y)}{\partial \tilde{\kappa}_y} > 0 \]

While it is relatively easy to prove proposition 3 by simply taking the derivative of welfare w.r.t. \( \tilde{\kappa}_y \) (and applying the implicit function theorem to differentiate \( \kappa_y \) w.r.t. \( \tilde{\kappa}_y \)), we can provide a more intuitive proof. The trick is to realize that we can change the variable of differentiation and apply the chain rule to rewrite \( \frac{\partial W(\tilde{\kappa}_y)}{\partial \kappa_y} \) as follows:

\[
\frac{\partial W(\tilde{\kappa}_y)}{\partial \tilde{\kappa}_y} = \frac{\partial W(\kappa_y(\tilde{\kappa}_y))}{\partial k_y} \frac{\partial k_y(\tilde{\kappa}_y)}{\partial \tilde{\kappa}_y}
\]

where \( \kappa_y(\tilde{\kappa}_y) \) is the implicit function defined by \( \kappa_y = (\varphi_a + \varphi_x(\kappa_y))^2 \tilde{\kappa}_y \). Remember that \( y_t \) is the exogenous signal obtained by using the equilibrium quantities to transform the endogenous public signal. The first component of the derivative is the effect on welfare of a higher precision of the public signal, when we treat the precision of \( y_t \) as exogenous. From lemma 1 we know that this effect is positive.
An increase in \( \bar{\kappa}_y \), however, has also another effect on welfare. As the signal about aggregate activity becomes more precise, agents change the way they use information in equilibrium. This, in turn, affects the precision of public information which is captured by the second component in the derivative. To determine the sign of \( \frac{\partial \kappa_y(\bar{\kappa}_y)}{\partial \bar{\kappa}_y} \), note that there are two opposing forces at work. First, an increase of \( \bar{\kappa}_y \) has the direct effect of increasing \( \kappa_y \). Second, an increase of \( \bar{\kappa}_y \) induces the agents to put less weight on their private signals thereby indirectly decreasing the precision of \( y_t \). In equilibrium the former effect must dominate the latter.

We can show that this is true by contradiction. In fact, suppose that the overall effect of a higher \( \bar{\kappa}_y \) was to decrease \( \kappa_y \). In this case, agents would put more weight on their private signals thereby leading to an increase in \( \kappa_y \). So, both effects would lead to an increase in \( \kappa_y \) contradicting our original claim.

### 4.2 Markup shocks

Let’s now consider markup shocks. As already hinted in the analysis of efficient shocks, a fundamental characteristic of this type of shocks is that they are a source of inefficient business cycles under complete information. Indeed, we know that if information was complete and a social planner was asked to allocate resources efficiently, she would eliminate the markups and hence the fluctuations they generate. Thus, under complete information, the business cycle caused by a varying monopoly power is not efficient.

One of the main contributions of this paper is to show that, under certain conditions, more information decreases welfare when the business cycle is generated by markup shocks. The conclusion of this section is therefore in stark contrast with the results obtained in the previous section. If the business cycle is inefficient under complete information, then under dispersed information more public information is detrimental for welfare.

To better highlight our results, in this section we are going to focus solely on markup shocks and shut down the other possible sources of business cycle. In particular, both productivity and taste shocks will be held constant and equal to their mean. Instead, markups are allowed to vary, with local markups equal to a common average markup plus an idiosyncratic component.

As in the previous section, we will first consider exogenous information, that is, a signal about the average markup; then we will make information endogenous by providing the agents with a signal about aggregate output (or aggregate employment).
4.2.1 Exogenous Information

The shocks and the available information satisfy the following properties.

First, the aggregate shock \( \bar{\mu}_t \) follows a Gaussian AR(1) or random walk process:

\[
\bar{\mu}_t = \psi \bar{\mu}_{t-1} + \nu_t,
\]

where \( \psi \) parameterizes the persistence of the composite shock and \( \nu_t \) is a Normal innovation, with mean 0 and variance \( \sigma^2_\nu = 1/\kappa_f \), i.i.d. over time.

Second, the local fundamental shock \( \mu_t \) is given by

\[
\mu_{it} = \bar{\mu}_t + \xi_{it},
\]

where \( \xi_{it} \) is a purely idiosyncratic shock, Normally distributed with mean 0 and variance \( \sigma^2_\xi \), orthogonal to \( \bar{\mu}_t \), and i.i.d. across islands. Note that the local fundamental \( \mu_{it} \) is itself a private signal of \( \bar{\mu}_t \).

Agents observe also a public signal about the aggregate shock \( \bar{\mu}_t \) given by a Gaussian random variable \( y_t \) such that

\[
y_t = \bar{\mu}_t + \varepsilon_t,
\]

where \( \varepsilon_t \) is a purely idiosyncratic shock, Normally distributed with mean 0 and variance \( \sigma^2_\varepsilon \), orthogonal to \( \bar{\mu}_t \), and common across islands. Denote with \( \kappa_\gamma \) the precision of this signal (\( \kappa_\gamma = 1/\sigma^2_\gamma \)).

Each agent can use the local markup to make inference about the average market power in the economy.

Let

\[
\beta_\mu \equiv \frac{1}{\frac{1}{\kappa_\gamma} + \gamma - 1},
\]

The following lemma uses (16), (17), and (18) to provide a closed-form solution to (8) when there are only markup shocks.

**Lemma 3.** When shocks and information are given by (16), (17), and (18), the equilibrium level of local output is given by

\[
\log q_{it} = \varphi_0 + \varphi_\mu \mu_{it} + \varphi_y y_t
\]

where the coefficients \( \varphi_0, \varphi_\mu, \varphi_y \) are given by

\[
\varphi_0 = (1 - \alpha) \beta_\mu, \quad \varphi_\mu = \left\{ \frac{(1 - \alpha) \kappa_x}{(1 - \alpha) \kappa_x + \kappa_y + \kappa_0} \right\} \beta_\mu, \quad \varphi_y = \left\{ \frac{\kappa_y}{(1 - \alpha) \kappa_x + \kappa_y + \kappa_0} \right\} \alpha \beta_\mu
\]
To derive the main result of this section, note that it is always possible to rewrite ex-ante welfare as follows:

\[ W(\mathbb{E}[Q], \sigma_Q^2, \sigma_q^2) = \frac{1}{1 - \gamma} \mathbb{E}[Q]^{1-\gamma} \exp\left\{-\frac{1}{2} \gamma (1 - \gamma) \sigma_Q^2\right\} - \frac{1}{\epsilon - 1} \mathbb{E}[Q]^{\gamma} \exp\left\{\frac{1}{2} \alpha_1 \sigma_Q^2 + \frac{1}{2} \alpha_2 \sigma_q^2\right\} \]

where \( \alpha_1 \) and \( \alpha_2 \) are two constants such that \( 0 < \alpha_1 < \alpha_2 \), \( \sigma_Q^2 \) is a measure of the volatility of economic activity, and \( \sigma_q^2 \) measures the dispersion of the production levels of the firms.

We can immediately draw some conclusions from this expression. Naturally, due to the concavity of the utility function, welfare is always decreasing in volatility and dispersion. However, the welfare effect of a higher mean level of equilibrium activity is ambiguous. For sufficiently low values of \( \mathbb{E}[Q] \), the representative consumer will be better off by consuming more, while also supplying more labor. For high values of \( \mathbb{E}[Q] \), however, the representative consumer will prefer to consume less and enjoy more leisure. There is a unique value of \( \mathbb{E}[Q] \) that maximizes welfare.

**Definition 2.** Let \( \mathbb{E}[Q]^* \) be the unique value of \( \mathbb{E}[Q] \) that maximizes \( W(\mathbb{E}[Q], \sigma_Q^2, \sigma_q^2) \), that is,

\[ \mathbb{E}[Q]^* = \arg \max_{\mathbb{E}[Q]} W(\mathbb{E}[Q], \sigma_Q^2, \sigma_q^2) \]

The value \( \mathbb{E}[Q]^* \) can be interpreted as the mean level of equilibrium activity that the planner would choose if he could control the average level of output before the shocks hit the economy. In fact, it is possible to show that a simple, non-contingent tax/subsidy allows the planner to achieve \( \mathbb{E}[Q]^* \). By definition, a non-contingent tax/subsidy does not depend on the state of the world and, in particular, it does not depend on the information available to the agents. Therefore, a non-contingent tax/subsidy does not affect the sensitivity of equilibrium activity to any information and thus volatility and dispersion also remain the same.

It turns out that more precise public information generally reduces welfare, provided that the average level of equilibrium activity is not too much lower than the optimal level.

**Proposition 4.** Welfare is decreasing in \( \kappa_g \) if and only if

\[ \log \mathbb{E}[Q]^* - \log \mathbb{E}[Q] < g, \quad g > 0 \] (19)

The specific value of \( g \), which depends only on parameters of the model, is given in the appendix with the proof of the proposition. You can think of the left-hand side of (19) as an ex-ante "output gap". It is the difference between the average level of output produced in equilibrium and the
average level of output that a planner would choose if restricted to using only non-contingent policies.

The reason why more public information about the average markup sometimes increases welfare is that a higher precision of public information affects also the average level of equilibrium activity \( E[Q] \). This is true for two reasons. First, remember that aggregate output is obtained by aggregating the output produced on every island with the Dixit-Stiglitz aggregator

\[
C_{h,t} = \left[ \int_I c_{hi,t}(d) \right]^{\frac{r}{r-1}}
\]

When the public signal becomes more precise, the agents will respond by putting more weight on this signal. This, in turn, makes the production levels of the islands less dispersed and, by the concavity of the Dixit-Stiglitz aggregator, mechanically increases the aggregate level of output.

Secondly, remember from (8) that the best response function of a firm is given by

\[
\log q_{it} = -(1 - \alpha) \beta \mu_{it} + \alpha \log \left( E_{it} \left[ \frac{Q_{it}^{1-\gamma}}{1-\gamma} \right] \right) \quad \forall i, t
\]

As the precision of the public signal increases and the agents put more weight on it, they face less uncertainty about aggregate output. Now, if \( \frac{1}{\rho} - \gamma > 0 \), the firm effectively behaves as a risk averse agent, producing more when aggregate output becomes less uncertain.

Proposition 4 then states that, unless the mean level of equilibrium activity is excessively low, the representative agent prefers having less information about markups, and therefore less socially inefficient fluctuations, than a higher average level of output.

An obvious consequence of proposition 4 is that more precise public information reduces welfare if the optimal non-contingent tax/subsidy is implemented.

**Corollary 1.** *If the social planner sets a non-contingent tax/subsidy on aggregate output or employment so as to maximize ex-ante welfare, then more precise public information reduces welfare.*

### 4.2.2 Endogenous Information

All the results considered in this section carry through in the case of endogenous information. In particular, as we did for productivity shocks, we can replace the public signal (18) with the endogenous signal

\[
y^0_t = \log Q_t + \tilde{\epsilon}_t, \quad \tilde{\epsilon}_t \sim N \left( 0, \frac{1}{\kappa^2} \right)
\]

In equilibrium our economy will be isomorphic to an economy with an exogenous public signal

\[
y_t = \tilde{\mu}_t + \epsilon_t, \quad \epsilon_t \sim N \left( 0, \frac{1}{\kappa^2} \right)
\]
where $\kappa_y$ is a fixed point of $\kappa_y = (\varphi_{\mu} + \varphi_{x}(\kappa_y))^2 \tilde{\kappa}_y$. As we did for productivity shocks, to compute $\frac{\partial W(y)}{\partial \kappa_y}$ we can change the variable of differentiation and apply the chain rule

$$\frac{\partial W(\kappa_y)}{\partial \kappa_y} = \frac{\partial W(\kappa_y(\tilde{\kappa}_y))}{\partial \kappa_y(\tilde{\kappa}_y)} \frac{\partial \kappa_y(\tilde{\kappa}_y)}{\partial \tilde{\kappa}_y}.$$ 

Hence, from an argument similar to the one made for productivity shocks, the conclusion of proposition 4 will be true also when information is endogenous.

### 4.3 Productivity and Markup Shocks

In this section we consider productivity and markup shocks together. From sections 4.1 and 4.2 we have learnt that the consequences for welfare of more precise public information depends on the nature of the shock causing the business cycle. In particular, when the business cycle is driven by productivity (or taste) shocks, and independently on whether information is exogenous or endogenous, more precise information always increases welfare. On the contrary, if the business cycle is driven by markup shocks, then more precise information reduces welfare, provided that condition (19) is satisfied.

The business cycle of a big economy is probably caused by many different shocks. Our analysis suggests that the consequences of providing better information are likely to depend on the nature of the shock with the biggest impact on the business cycle. Unfortunately, what are the shocks causing economic fluctuations and what is their relative importance are among the most difficult questions in economics. It seems natural, therefore, to adopt an agnostic approach on the relative importance of different shocks and present the results as their relative weights vary.

More specifically, we imagine the economy as being hit by two different shocks, productivity and markup shocks. Agents observe local productivity, local markups, and also a noisy signal about aggregate economic activity. Since the economy is now hit by two different shocks, in equilibrium the latter will be equivalent to an exogenous signal about a linear combination of aggregate productivity and aggregate monopoly power.

Formally, assume that aggregate productivity follows a Gaussian AR(1) process:

$$\bar{a}_t = \psi_a \bar{a}_{t-1} + \nu^a_t,$$

where $\psi_a$ parameterizes the persistence of the composite shock and $\nu^a_t$ is a Normal innovation, with mean 0 and variance $\sigma^2_{\nu_a} = 1/\kappa_f$, i.i.d. over time. Similarly, aggregate markup follows a Gaussian AR(1) process:

$$\bar{\mu}_t = \psi_{\mu} \bar{\mu}_{t-1} + \nu^\mu_t,$$
where $\psi_\mu$ parameterizes the persistence of the composite shock and $\nu_t^\mu$ is a Normal innovation, with mean 0 and variance $\sigma_{\nu_t^\mu}^2 \equiv 1/\kappa_f$, i.i.d. over time.

Agents also learn local productivity and local markups. Formally, they observe

$$a_{it} = \bar{a}_t + \xi_{it}^a,$$

and

$$\mu_{it} = \bar{\mu}_t + \xi_{it}^\mu,$$

where $\xi_{it}^a$ and $\xi_{it}^\mu$ are purely idiosyncratic shocks, Normally distributed with mean 0 and variance respectively $\sigma_{\xi_t^a}$ and $\sigma_{\xi_t^\mu}$, and orthogonal to $\bar{a}_t$ and $\bar{\mu}_t$, and i.i.d. across islands.

Finally, every agents observes a noisy signal of aggregate economic activity,

$$\bar{y}_t = \log Q_t + \tilde{\varepsilon}_t$$

where $\tilde{\varepsilon}_t$ is an idiosyncratic shock, common to every agent, Normally distributed with mean 0 and variance $\tilde{\sigma}_y^2$.

In the appendix we characterize the equilibrium and we show that in equilibrium $y_t^a$ is equivalent to the exogenous signal

$$y_t = \varphi_a \bar{a}_t + \varphi_\mu \bar{\mu}_t + \tilde{\varepsilon}_t$$

(20)

where $\varphi_a$ and $\varphi_\mu$ are the sensitivities of the equilibrium strategy to $a_{it}$ and $\mu_{it}$, respectively.

What matters is that now (20) is a combination of the two aggregate shocks. The analysis in the previous sections inform us on the implications for welfare of more precise information in the special cases of $\sigma_{\nu_t^\mu}^2 = 0$ (only productivity shocks) and $\sigma_{\nu_t^a}^2 = 0$ (only markup shocks). A convenient way to present our results without taking a stand on how much each shock matters for the business cycle is to parametrize the relative importance of the two shocks with $R \equiv \sigma_{\nu_t^a}^2 / (\sigma_{\nu_t^a}^2 + \sigma_{\nu_t^\mu}^2)$. Hence, $R$ ranges between 0 and 1; $R = 0$ represents the case of only markup shocks and, as $R$ increases towards 1, productivity shocks become relatively more important.

We solve the model numerically. We calibrate the model interpreting a period as a quarter. We choose $\sigma_{\xi_t^a}^2 = \sigma_{\xi_t^\mu}^2 = 0.01$ to roughly match the observed dispersion of markups and productivity levels in the US economy. Next, to calibrate the standard deviation of the endogenous signal $\tilde{\sigma}_y$ we look at the BEA releases of quarterly GDP. For a given quarter, the BEA publishes different estimates of GDP as more information becomes available. We assume that the last estimate is the true value of GDP. We set $\tilde{\sigma}_y = 0.02$, which is close to the standard deviation of the error between the first and the last release found in the literature.
Also, we choose $\sigma_{\nu a}^2$ and $\sigma_{\nu \mu}^2$ to target a quarterly GDP growth of 0.02. The calibration, however, does not pin down an exact value for the two variances. We therefore let the ratio $\sigma_{\nu a}^2/ (\sigma_{\nu a}^2 + \sigma_{\nu \mu}^2)$ be equal to $R$. The choice of the other parameters is standard. We assume constant return to scale, $\theta = 1$, and set $\epsilon$, the inverse of the Frisch elasticity of labor supply, equal to 0.2. Since, in a model with no capital, the intertemporal elasticity of substitution is irrelevant, the parameter $\gamma$ controls only the income elasticity of labor supply. Accordingly, in our simulations we choose $\gamma = 0$, except in one case when we set $\gamma = 0.2$, so that we obtain a negative value for $\alpha$. The average markup is 0.15, which is roughly consistent with the estimates for the US economy and satisfies condition (19).

Finally, a typical way to calibrate $\rho$ is to use the restriction that $\rho = \eta$, that is, to assume that the elasticity of demand faced by firms within an island is the same as the elasticity of substitution across islands. With this restriction, we can back out a value for $\rho$ by using the fact that the average $\eta$ is identified by the average markup. Our baseline value for $\rho$ will be 5 (corresponding to an average markup of about 25%), which implies a degree of strategic complementarity equal to 0.5. However, we present results also for other values of $\alpha$ (equivalently, $\rho$) to show that our conclusion does not depend on the value or sign of $\alpha$.

Figure 1: Welfare effect of more precise information as a function of $R$.

Figure (1) plots the welfare effect of more precise information as a function of $R$. The exercise is to compare the economy with $\tilde{\sigma}_y = 0.02$ to the economy when $\tilde{\sigma}_y = 0$, that is, we make the information provided to the public as precise as possible. The welfare gain (or loss) is measured in consumption equivalent units relative to the cost of the business cycle in the complete information benchmark. For example, a value of $-0.1$ means that the representative agent would give up as
much as 10% of the consumption he would forego to have $\sigma_{\nu a}^2 = \sigma_{\nu \mu}^2 = 0$ in the model with no dispersed information.

Intuitively, the figure shows that for low values of $R$, that is, when the business cycle is mainly driven by markup shocks, more precise information reduces welfare. As $R$ increases, however, productivity shocks become relatively more important and more information will tend to improve welfare. Also, note that the conclusion does not depend on the sign or value of $\alpha$. This confirms our hypothesis: what matters to determine whether information improves welfare is the nature of the shock hitting the economy, not the degree of strategic complementarity.

5 Monetary Extension

[to be completed]