

Expectations and Fluctuations: The Role of Monetary Policy *

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Abstract

This paper reconsiders the effects of expectations on economic fluctuations. It does so within a competitive monetary economy featuring producers and consumers with heterogeneous information about productivity. Agents' expectations are coordinated by a noisy public signal which generates non-fundamental, purely expectational shocks. Agents' expectations, however, have different implications for the economy. Hence, depending on how monetary policy is pursued, purely expectational shocks can behave like either demand shocks, as conventionally thought, or supply shocks—increasing output and employment yet lowering inflation. On the policy front, conventional policy recommendations are overturned: inflation stabilization is suboptimal, whereas output-gap stabilization is optimal.

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1 Introduction

Expectations take center stage in macroeconomics. Having acknowledged their importance in the most emphatic of ways, the US Federal Reserve recently started publishing its own forecasts of its own interest rate. But, even though recent empirical work documents that shocks to expectations indeed contribute significantly to economic fluctuations,¹ the exact way they do so, what drives

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¹ Empirical studies documenting the major contribution of shifts in expectations to business cycle fluctuations include [Beaudry and Portier \(2006\)](#), [Beaudry and Lucke \(2010\)](#), [Barsky and Sims \(2011, 2012\)](#), [Schmitt-Grohe and Uribe \(2012\)](#) and [Blanchard et al. \(2012\)](#).

them or how they can be handled remain open questions.

In pursuit of the answers, academics, practitioners, and op-ed columnists might still be debating, yet there is something they all agree on: when the public overstates the economy’s potential, the economy booms at the cost of inflation. A recent literature has explicitly formalized this idea:² non-fundamental, purely expectational, shocks behave like demand shocks; when positive, they increase output and employment, and they push inflation up. Stabilizing inflation emerges then as a natural policy recommendation.³

Nonetheless, consumer sentiment and inflation exhibited an in fact negative correlation (-0.53) in the US over the period 1965-2010 (Figure 1). On top of this, in the second half of the 90s, a period recalled and registered as one of exuberant optimism, the US economy combined high cyclical employment with low inflation. In particular, between 1995:1-2001:4 consumer sentiment and cyclical employment exhibited a strong positive correlation ($+0.77$), whereas over the extended period 1990:1-2002:4 (Figure 2) consumer sentiment exhibited a positive correlation with cyclical employment ($+0.44$) maintaining the negative one with inflation (-0.41).⁴

This paper reconsiders the role of expectations in economic fluctuations. It does so within a competitive economy featuring two representative agents, a consumer/worker and a producer, and a monetary authority. The worker supplies labor to a firm, managed by the producer. Productivity is specific to the worker and consists of a permanent (long-run) and a temporary component. It is unknown to the producer, with its decomposition being unknown to the worker too.

Activity in each period is spread over two stages. In the first stage, the worker realizes his current productivity—not its individual components, both agents observe a noisy public signal about the permanent productivity component, and the labor market opens (and closes). In the second stage, with production pre-determined from stage 1, consumption and saving decisions are made and the nominal interest rate is set by the monetary authority according to a standard Taylor rule. Agents are price-takers and prices flexible.

The nominal wage, announced in stage 1, reflects producer expectations about productivity as

²See for example [Blanchard \(2009\)](#), [Angeletos and La’O \(2009\)](#), and especially [Lorenzoni \(2009, 2011\)](#).

³See the baseline case in [Lorenzoni \(2009\)](#).

⁴Data in Figures 1 and 2 are quarterly and refer to the US economy. They span the period 1965:1-2010:1 in Figure 1 and 1990:1-2002:4 in Figure 2. Inflation refers to percent changes in the “Gross Domestic Product: Implicit Price Deflator” (series GDPDEF) and is seasonally adjusted. Consumer Sentiment refers to “University of Michigan: Consumer Sentiment” (series UMCSENT1, UMCSENT) and is not seasonally adjusted. For expositional clarity, I have scaled it down by 25 in Figure 1 and 75 in Figure 2. Employment in Figure 2 refers to “All Employees: Total Nonfarm Employees (Thousands of Persons)” (series PAYEMS) and is seasonally adjusted. It is logged and HP-filtered with penalty 1600. I have scaled up its cyclical component by 50. All data are from the St. Louis Fed.

well as stage-2 inflation. Inflation, in turn, depends on current productivity, producer expectations about it, and consumer expectations about long-run productivity in a way decided by monetary policy. Asymmetric information about current productivity leads agents to form heterogeneous expectations about stage-2 inflation; it is exactly this that opens the door to monetary policy. Further, to the extent that inflation depends on consumer long-run expectations, the producer needs to second-guess the consumer. Consumer expectations have then real effects too and they do so, indirectly, through inflation.

Agents' expectations, however, have different implications for the economy. To see this, consider a positive shock to the noise component of the public signal, which is—and I will henceforth call—a purely expectational shock. Consumer expectations about long-run productivity push toward a demand-shock interpretation. A consumption smoothing motive underlies this. A consumer overly optimistic about the long-run prospects of the economy raises his current demand. Under incomplete information, the producer overestimates the inflationary pressure to be caused due to the consumer's expectations. As a result, the nominal wage increases more than proportionally relative to prices and a higher real wage prevails. This induces the worker to increase his labor supply and production to expand. On the other hand, producer expectations about current productivity point toward a supply-shock interpretation. A higher real wage reflects the producer's overly optimistic expectations. As a result, employment increases, production expands and, at a certain demand level, prices need to fall for the consumption-good market to clear.

Whether purely expectational shocks eventually behave like demand or supply shocks depends on the monetary policy pursued and it is precisely this the message my paper bears. The policy weight on the current output gap proves in particular crucial as to which effect dominates. To see this, consider an interest rate rule targeting current inflation and the current output gap and fix the nominal interest rate at a certain level. Following a positive purely expectational shock both agents' effects lead to a positive output gap. The greater the weight on the output gap, the lower the inflationary pressure which, in fact, may turn to a deflationary one.

An analogous reasoning applies to productivity shocks. Following a positive productivity shock, agents' expectations underreact since agents attribute part of the observed high signal to its noise component. As a result, a lower real wage prevails which induces employment to fall;⁵ output increases, however less than under complete information. Once again, the weight on the output gap

⁵ [Gali \(1999\)](#) and [Basu et al. \(2006\)](#) are papers from the business cycle literature also arguing that positive technology shocks cause a temporary fall in employment.

determines whether productivity shocks push inflation up or down.

Concluding with welfare, since the producer’s incomplete information is the only source of inefficiency, a monetary authority should restore the complete information equilibrium. To do so it needs to manipulate inflation in a way such that the producer correctly anticipates his stage-2 revenue. By stabilizing inflation it fails to do so because it eliminates the producer’s uncertainty only about the prices he will sell at in stage 2, while it does nothing to ameliorate his uncertainty about the quantity to be sold. Interestingly, output-gap stabilization restores optimality: a monetary authority ready to take infinitely punitive action against potential deviations of output from its natural level renders producer expectations irrelevant.

Relation to the literature. That shifts in expectations play a major role in business cycle fluctuations is an idea with origins at least in [Pigou \(1926\)](#). This idea has recently been revived by the “news shocks” literature which includes articles by [Beaudry and Portier \(2004, 2006, 2007\)](#), [Jaimovich and Rebelo \(2009\)](#), [Christiano et al. \(2010\)](#), and [Barsky and Sims \(2011\)](#). [Christiano et al. \(2010\)](#) document and subsequently show theoretically within a New Keynesian framework that positive shocks to expectations about future productivity drive output gap (and asset prices) up and inflation down. This point is akin to the supply-shock manifestation of purely expectational shocks which my paper puts forward as a possibility. However, [Christiano et al. \(2010\)](#) and, generally, the “news shocks” literature distinguish between shocks to current and (anticipated) shocks to future productivity, whereas, crucially, my paper distinguishes between fundamental and non-fundamental shocks to expectations.

As such, my paper naturally lies in the literature following [Phelps \(1970\)](#) and [Lucas \(1972\)](#) which formalized the idea that incomplete information can open the door to non-neutralities of non-fundamental factors and, in particular, monetary ones.⁶ This literature has also been revived over the last years, however its focus has shifted from monetary to aggregate information shocks.⁷

Like the recent literature, my paper lets information give rise to aggregate shocks and it entirely

⁶ Related papers of the early literature include [Polemarchakis and Weiss \(1977\)](#), [Weiss \(1980\)](#), [King \(1982\)](#), [Bulow and Polemarchakis \(1983\)](#) and, especially, [Grossman and Weiss \(1982\)](#).

⁷The recent literature is developing in different yet complementary directions. For instance, following [Phelps \(1983\)](#), the works of [Woodford \(2001\)](#), [Morris and Shin \(2002\)](#), [Hellwig \(2002\)](#), [Angeletos and Pavan \(2007, 2009\)](#), [Nimark \(2008, 2011\)](#), [Angeletos et al. \(2011\)](#) and [Angeletos and La’O \(2009, 2012b\)](#) emphasize (or formalize within a business-cycle context in the case of [Angeletos and La’O \(2012b\)](#)) the role of higher-order beliefs. [Mankiw and Reis \(2002\)](#), [Sims \(2003\)](#), [Adam \(2007\)](#), [Mackowiak and Wiederholt \(2009\)](#) and [Paciello and Wiederholt \(2011\)](#) among other articles emphasize the role of information-processing constraints which [Coibion and Gorodnichenko \(2012\)](#) explore empirically. Excellent surveys of both the early and the more recent literature are offered in [Hellwig \(2008\)](#), [Mankiw and Reis \(2010\)](#), [Lorenzoni \(2011\)](#) and [Veldkamp \(2011\)](#).

abstracts from monetary policy shocks: the very existence of incomplete information is independent of the monetary authority’s actions. Nonetheless, monetary policy takes center stage: it is non-neutral because agents have asymmetric information about variables the monetary authority will respond to, an idea my paper shares among others with [Weiss \(1980\)](#), [King \(1982\)](#) and [Lorenzoni \(2010\)](#).⁸ In a sense, monetary policy acts here as a lever and, depending on how it is pursued, it scales up or down the effects of aggregate shocks.

The closest paper to mine is [Lorenzoni \(2009\)](#). [Lorenzoni \(2009\)](#) asks whether purely expectational shocks can behave like demand shocks and answers that, indeed, they can so. To show this, it restricts attention to the consumer side within a New Keynesian environment. My paper, instead, considers both the producer and the consumer side within a competitive price-taking environment. Rather more broadly, it asks how purely expectational shocks behave and argues that the answer depends on how monetary policy is pursued. To the best of my knowledge, my paper is the first to suggest so. Hence, purely expectational shocks can indeed behave like demand shocks, as [Lorenzoni \(2009\)](#) suggests, but they can well behave like supply shocks in response to different monetary policies. In the latter case, they push employment and inflation in opposite directions, which is at odds with the Phillips curve and further differentiates my paper from [Lucas \(1972\)](#) and the related literature.

A supply-shock behavior can reconcile purely expectational shocks with the empirical finding of [Barsky and Sims \(2012\)](#), namely, that shocks to expectations about future productivity (which can, in principle, be fundamental or non-fundamental) raise output and lower inflation. Purely expectational shocks within the New Keynesian DSGE model of [Barsky and Sims \(2012\)](#) fail to do so which leads the authors to essentially dismiss them as unable to account for the dynamics of aggregate variables. [Blanchard et al. \(2012\)](#), on the contrary, favors a demand-shock interpretation of purely expectational shocks an argument made within a framework similar to [Lorenzoni \(2009\)](#). Nevertheless, the authors themselves admit that “to identify the role of news and noise in fluctuations one must rely more heavily on the model’s structure.”

Concluding with the optimal policy literature, [Angeletos and La’O \(2012a\)](#) is a recent contribution studying optimal monetary policy under incomplete information.⁹ Even though it does so within a quite different environment (monopolistically-competitive one with a cash-in-advance constraint)—which makes comparisons rather hard—it shares a key policy implication with my paper

⁸Crucially, it is asymmetric as opposed to incomplete yet symmetric information that breaks the policy irrelevance proposed in [Sargent and Wallace \(1975, 1976\)](#).

⁹ Among others, recent related papers include [Adam \(2007\)](#), [Lorenzoni \(2010\)](#) and [Paciello and Wiederholt \(2011\)](#).

and, in that sense, the two papers complement each other: inflation stabilization is suboptimal. This is because incomplete information acts as a real distortion eventually breaking the so-called “divine coincidence,” an insight also offered by [Blanchard and Gali \(2007\)](#).

The rest of the paper is structured as follows. Sections 2 presents the model. Section 3 demonstrates the equilibrium results. Section 4 discusses welfare and juxtaposes different policies. Section 5 concludes.

2 Environment

A competitive economy features two agents: a representative consumer/worker supplying labor to a representative firm he owns and a producer managing the firm. The firm produces a non-storable commodity. The economy is cashless and the only relevant financial market is a short-term nominal bond market. The price of the riskless short-term nominal bond is set by a monetary authority according to an interest-rate rule.¹⁰ Agents are price-takers in all markets they participate. Time is discrete and infinite and commences in period 0.

The consumer’s preferences are given by

$$E_{-1}^c \sum_{t=0}^{\infty} \beta^t U(C_t, N_t), \quad (1)$$

with period- t utility given by

$$U(C_t, N_t) = \log C_t - \frac{1}{1+\zeta} N_t^{1+\zeta}. \quad (2)$$

C_t denotes consumption and N_t denotes employment in period t ; $\zeta > 0$ denotes the inverse of the constant marginal utility of wealth (“Frisch”) elasticity of labor supply; $\beta \in (0, 1)$ parametrizes the consumer’s time preference.

The consumer faces a sequence of budget constraints given by

$$P_t C_t + Q_t B_{t+1} = B_t + W_t N_t + \Pi_t. \quad (3)$$

Q_t denotes the nominal bond price and B_{t+1} denotes holdings of nominal bonds maturing in $t+1$; P_t denotes the commodity price and W_t denotes the nominal wage in t ; Π_t denotes the firm’s profits that accrue to the consumer.

The firm’s technology is

$$Y_t = A_t N_t, \quad (4)$$

¹⁰Chapters 1 and 2 in [Woodford \(2003\)](#) discuss cashless monetary economies.

where Y_t denotes the firm's output and A_t denotes the worker's productivity. The firm's profits are given by

$$\Pi_t = P_t Y_t - W_t N_t. \quad (5)$$

A monetary authority sets the nominal bond price according to the following interest-rate rule:^{11,12}

$$Q_t = \beta \Pi_t^{-\phi_\pi} \left(\frac{Y_t}{Y_t^*} \right)^{-\phi_y}. \quad (6)$$

Π_t denotes inflation in period t , defined as $\Pi_t \equiv \frac{P_t}{P_{t-1}}$; Y_t^* denotes the optimal output level in period t . The policy parameters ϕ_π and ϕ_y take non-negative values.

2.1 Shocks

Productivity consists of a permanent and a temporary component (henceforth, lowercase variables will denote natural logarithms of the respective uppercase variables),

$$a_t = x_t + u_t, \quad (7)$$

where x denotes the permanent productivity component and u denotes the temporary productivity component.¹³ Productivity—not its components—is specific to and known by the worker, whereas the producer faces uncertainty about it.¹⁴

The permanent productivity component x_t follows a random walk stochastic process

$$x_t = x_{t-1} + \epsilon_t, \quad (8)$$

where ϵ_t is an i.i.d shock and $\epsilon \sim N(0, \sigma_\epsilon^2)$. The temporary productivity component u_t is i.i.d. and $u \sim N(0, \sigma_u^2)$.

All agents have costless access to a public signal about the permanent productivity component

$$s_t = x_t + e_t, \quad (9)$$

¹¹ This rule has been suggested by [Taylor \(1993, 1999\)](#) to capture adequately the Fed's policy during the period 1987-1992.

¹² The existence of a monetary policy rule is necessary -but not always sufficient- to get round the equilibrium indeterminacy, nominal or real depending on whether agents have complete information or not, that would have prevailed in its absence.

¹³ Shocks are as in [Lorenzoni \(2009\)](#).

¹⁴ It could be argued that it is in the worker's best interest to reveal his type as he is the firm's owner. This is only an abstraction. Even though I have not explored this possibility, an economy with many islands and complete financial markets which preserves the asymmetry of information within an island would presumably generate similar implications. See also fn. 20.

where e_t is i.i.d. and $e \sim N(0, \sigma_e^2)$. Hereafter, I will call e a purely expectational shock.¹⁵

Shocks ϵ_t , u_t , and e_t are mutually independent.

2.2 Timing

Each period is divided into two stages: in the first stage, only the labor market opens (and closes), whereas, in the second stage, the commodity market and the nominal bond market open. All payments materialize in stage 2 and are perfectly enforceable.

Stage 1 is in turn divided into two sub-stages: in sub-stage 1, the consumer/worker realizes his productivity a_t , both agents and the monetary authority realize the public signal about the permanent productivity component s_t , and the nominal wage prevails; in sub-stage 2, the worker decides on his labor supply. This intra-stage distinction is made possible by the firm's technology given by (4): constant returns to scale imply that the nominal wage is independent of the amount of labor to be submitted in sub-stage 2 of stage 1.¹⁶

In stage 2, the monetary authority steps in to set the nominal interest rate according to the interest-rate rule given by (6) and the commodity market opens. The consumer decides on his bond holdings and consumption at the prevailing prices. With nominal bonds in zero net supply, the nominal bond price adjusts to clear the nominal bond market; with production pre-determined from stage 1, the commodity price adjusts to clear the commodity market.

I will show below that output (alternatively, the commodity price) perfectly reveals productivity. This implies that in stage 2 of each period both agents and the monetary authority have identical information.

3 Rational Expectations Equilibrium

The state of the economy in period t coincides with the entire history of observables $\Psi_t = \{(a_\tau)_{\tau=0}^t, (s_\tau)_{\tau=0}^t\}$. This is so due to the agents' formation of expectations on which I elaborate below. Turning to the agents and the monetary authority's information sets, my last comment in the previous section

¹⁵The distinction between permanent and temporary productivity shocks together with the fact that the public signal is about the former implies that the effects of purely expectational shocks persist.

¹⁶I have introduced a lag in the labor supply decision in order to prevent it from fully revealing the worker's productivity. Were technology instead to exhibit decreasing returns to scale, such a possibility would not be available. An alternative in that case could be to let labor supply be subject to additional, idiosyncratic to the worker, shocks (e.g. a preference shock). Labor supply would then (generically) be partially revealing about the worker's productivity. In the limit case in which the shock's variance tended to infinity, the producer would dismiss the informational content of labor supply and his information set would coincide with the one here.

implies that the producer's information set in sub-stage 1 of stage 1 of period t is $I_{t,1}^p = \Psi_t \setminus \{a_t\}$, whereas the information sets of both agents and the monetary authority coincide with the state of the economy in stage 2 of each period: $I_{t,2}^p = I_{t,2}^m = I_t^c = \Psi_t$. Subscripts indicate the period and, where applicable, the stage.

Definition 1 (Equilibrium). *A rational expectations equilibrium under an interest-rate rule $Q_t(\Psi_t)$ consists of prices $\{P_t(\Psi_t), W_t(\Psi_t \setminus \{a_t\})\}$, an allocation $\{N_t^d(\Psi_t \setminus \{a_t\}), Y_t(\Psi_t)\}$ for the producer and an allocation $\{C_t(\Psi_t), N_t^s(\Psi_t), B_{t+1}(\Psi_t)\}$ for the consumer such that:¹⁷*

1. $\{N_t^d(\Psi_t \setminus \{a_t\}), Y_t(\Psi_t)\}$ solves the producer's problem, laid out below, at prices $\{P_t(\Psi_t), W_t(\Psi_t \setminus \{a_t\}), Q_t(\Psi_t)\}$.
2. $\{C_t(\Psi_t), N_t^s(\Psi_t), B_{t+1}(\Psi_t)\}$ solves the consumer's problem, laid out below, at prices $\{P_t(\Psi_t), W_t(\Psi_t \setminus \{a_t\}), Q_t(\Psi_t)\}$.
3. All markets clear: $Y_t = C_t$, $N_t^d = N_t^s$, $B_{t+1} = 0$ for all t with $B_0 = 0$.

Let me start with the consumer. The consumer has complete information about the state of the economy. Therefore, he effectively makes all decisions in stage 1. Given $B_0 = 0$, the consumer chooses consumption, labor supply, and nominal bond holdings to maximize his expected utility (1)-(2) subject to his sequence of budget constraints (3), and a no-Ponzi-scheme constraint (for instance, $B_{t+1} > -\Gamma$ for any $\Gamma > 0$ at all t). The consumer's optimality conditions are

$$N_t^\zeta = \frac{W_t}{P_t C_t} \quad (10)$$

$$Q_t = \beta E_t^c \left[\frac{P_t}{P_{t+1}} \frac{C_t}{C_{t+1}} \right], \quad (11)$$

where Q_t is given by (6), while $E_t^c[\cdot]$ refers to the consumer's expectations conditional on his information set I_t^c .¹⁸

In addition, the no-Ponzi-scheme constraint and the fact that nominal bonds are in zero net supply imply that $B_{t+1} = 0$ for all t in equilibrium. Suppressing then bond holdings from the state of the economy is harmless.

¹⁷Since production takes place after the nominal wage is announced and depends on the consumer/worker's productivity, Y_t is a function of the state Ψ_t rather than the producer's information set in stage 1, $I_{t,1}^p = \Psi_t \setminus \{a_t\}$.

¹⁸Since the consumer's information set does not change within a period, I have made no distinction between stages 1 and 2 for the consumer's expectations.

The producer's labor demand in stage 1 maximizes the firm's expected evaluated profits, $E_{t,1}^p [\lambda_t \Pi_t]$.¹⁹ Profits are given by (5) and are evaluated using the consumer/owner's Lagrange multiplier, $\lambda_t = (P_t C_t)^{-1}$.²⁰ Given the constant-returns-to-scale technology, solving the producer's problem implies that the producer accommodates any labor supply at²¹

$$W_t = \frac{E_t^p [\lambda_t P_t A_t]}{E_t^p [\lambda_t]}. \quad (12)$$

In what follows, I restrict attention to linear rational expectations equilibria.²² This simplifies considerably the agents' information extraction problems and allows me to use the Kalman filter algorithm in order to study the evolution of agents' beliefs.²³

In log-linear form, optimality conditions (10)-(12) are²⁴

$$\zeta n_t = w_t - p_t - c_t \quad (13)$$

$$c_t = -\log \beta + \log Q_t + E_t^c [c_{t+1} + \pi_{t+1}] + \text{const} \quad (14)$$

$$w_t = E_t^p [a_t] + E_t^p [p_t] + \text{const}' \quad (15)$$

Further, interest-rate rule (6) in log-linear form is

$$i_t \equiv \log \frac{1}{Q_t} = -\log \beta + \phi_\pi \pi_t + \phi_y (y_t - y_t^*). \quad (16)$$

¹⁹The producer's expectations are conditional on the producer's information set in sub-stage 1 of stage 1, $I_{t,1}^p$. Unless otherwise stated, this will henceforth be the case, therefore I will drop 1 from the subscript.

²⁰One may correctly point out that the consumer's Lagrange multiplier would perfectly reveals his productivity. Implicitly I have assumed that, at the beginning of the each period, the consumer and the producer physically separate. This assumption allows me to abstract from the "Lucas-Phelps" islands framework and consider only one "island" in its stead. Given this, by maximizing the firm's evaluated profits, the producer operates the firm in the way the consumer/owner would want him to (see also Chapter 6 in Magill and Quinzii (1996)).

²¹It is central to the paper that the nominal wage in stage 1 be such that the producer's expected evaluated profits are zero. Given the linear technology (4), the producer is willing to hire any labor supplied at that nominal wage given by (12). This will typically result in a production level not ex-post desirable: once the state of the economy is realized, the real wage will typically be higher or lower than productivity, yielding losses or profits, respectively, to the firm with losses (profits) subtracted (added) in a lump-sum fashion from (to) the consumer/owner's period wealth. Even though the nominal wage is flexible and competitive, the current setting could be roughly thought to imply some form of nominal wage stickiness.

²²I ignore whether non-linear equilibria exist.

²³Since permanent productivity follows a random walk, output and consumption are non-stationary and the steady state is stochastic (see also fn. 41). To restore stationarity one would need to normalize the non-stationary variables with the permanent productivity component (see also King et al. (1988) and Lorenzoni (2005)). I find it more convenient though to work throughout with the non-normalized variables.

²⁴Appendix A.2 keeps track of the constant terms which I shortly bring back to discussion.

Combining (13) with (15) and (14) with (16) results in the two optimality conditions which we will need from here onwards:²⁵

$$\zeta n_t = E_t^p [a_t] + E_t^p [\pi_t] - \pi_t - c_t + \text{const}' \quad (17)$$

$$E_t^c [c_{t+1}] - c_t = \phi_\pi \pi_t + \phi_y (y_t - y_t^*) - E_t^c [\pi_{t+1}] + \text{const}. \quad (18)$$

3.1 Expectations and the state of the economy

Agents and the monetary authority's expectations about permanent productivity evolve according to the Kalman filter algorithm. This means that past realizations of productivity and the public signal (the observables) are part of the current state of the economy, which, consequently, coincides with the entire history. In particular,

$$E_{t,1}^p [a_t] = E_{t,1}^p [x_t] = (1 - \mu) E_{t-1,2}^p [x_{t-1}] + \mu s_t \quad (19)$$

$$E_{t,2}^p [x_t] = E_{t,2}^m [x_t] = E_t^c [x_t] = (1 - k) E_{t-1}^c [x_{t-1}] + k [\theta s_t + (1 - \theta) a_t], \quad (20)$$

where μ, k, θ depend on the variances $\sigma_\epsilon^2, \sigma_u^2, \sigma_e^2$ and lie in $(0, 1)$. The first equality in (19) follows from (7). The second equality in (19) follows from the fact that $I_{t,1}^p = \Psi_t \setminus \{a_t\}$, whereas the first two equalities in (20) follow from the fact that $I_{t,2}^p = I_{t,2}^m = I_t^c = \Psi_t$. In the following section I show why these are so. Further, I will argue that the way agents form expectations disciplines the way signals enter the state. Appendix A.1 offers a detailed treatment of the expectations formation.

3.2 Complete information benchmark

Suppose that the state of the economy is common knowledge, that is $I_t^p = I_t^m = I_t^c = \Psi_t$. The real side of the economy is then determined irrespectively of the public signal and the pursued monetary policy: we can confirm that $n_t^* = 0$ and $y_t^* = a_t$.

On the nominal side, conjecture that $\pi_t = \vartheta_0 + \vartheta_1 E_t^c [x_t] + \vartheta_2 a_t$; then use (18) to confirm that $\pi_t^* = \vartheta_0 + \frac{1}{\phi_\pi} (E_t^c [x_t] - a_t)$ with ϑ_0 given by (43). The consumer's expectations about permanent (long-run) productivity have only nominal effects. A consumption smoothing motive leads to changes in the consumer's current demand depending on the consumer's expectations about permanent productivity. As a result, flexible prices respond in stage 2 accordingly (note that

²⁵On the RHS of (17) I add and subtract p_{t-1} .

prices increase in $E_t^c[x_t]$, a point I revisit below). However the nominal wage proportionally adjusts in stage 1 leaving, thereby, the real wage intact and preventing the consumer's expectations from having real effects.

3.3 Incomplete information

Let me post the following conjectures:²⁶

$$c_t = \xi_0 + \xi_1 E_t^p[a_t] + \xi_2 a_t \quad (\text{C1})$$

$$\pi_t = \kappa_0 + \kappa_1 E_t^p[a_t] + \kappa_2 E_t^c[x_t] + \kappa_3 a_t. \quad (\text{C2})$$

Conjectures (C1) and (C2) imply that the producer and the monetary authority can fully extract productivity in stage 2 by either observing production (given market clearing) or inflation.²⁷ This establishes that $I_{t,2}^p = I_{t,2}^m = I_t^c = \Psi_t$.

Conjectures (C1) and (C2), optimality conditions (17) and (18), and market clearing together imply that

$$y_t = \xi_0 + \xi_1 E_t^p[a_t] + (1 - \xi_1) a_t \quad (21)$$

$$\pi_t = \kappa_0 + \frac{1}{\phi_\pi} [-(1 + \phi_y) \xi_1 E_t^p[a_t] + E_t^c[x_t] + [(1 + \phi_y) \xi_1 - 1] a_t] \quad (22)$$

$$\xi_1 = \frac{\phi_\pi - 1 + k(1 - \theta)}{\phi_\pi(1 + \zeta) - (1 + \phi_y)}, \quad (23)$$

where k and θ are parameters associated with the consumer's learning problem derived in Appendix A.1, ξ_0 is given by (72) and κ_0 is given by (66). Appendix A.2 collects all derivations leading to (21) - (23).

Equation (21) shows that output is a weighted average²⁸ of productivity and the producer's expectations about it. The respective weights depend on the Frisch elasticity of labor supply, parametrized by ζ , and, importantly, the monetary policy parameters ϕ_π , ϕ_y .

²⁶Conjecturing instead that consumption and inflation depend on the entire history of public signals and productivities would make no difference. This is a direct consequence of the way agents form expectations, described in Section 3.1, which disciplines the treatment of public signals and productivities within the state.

²⁷Confirm this from (21) - (23) below bearing in mind that the policy variables ϕ_π , ϕ_y do not take negative values.

²⁸This is a direct consequence of preferences being logarithmic in consumption.

The presence of ϕ_π , ϕ_y in (21) leads to the first remark: monetary policy is non-neutral. To see why, express first the labor market optimality condition (17) in the following more general way:

$$\zeta n_t = E_t^p[a_t] + E_t^p[\pi_t] - E_t^c[\pi_t] - E_t^c[c_t] + \text{const}' . \quad (24)$$

To the extent that it affects inflation, monetary policy has real effects as long as agents form heterogeneous expectations about the inflation to prevail in stage 2. That is when $E_t^p[\pi_t] \neq E_t^c[\pi_t]$, by construction, the case here. Of course, heterogeneous expectations are attributed to the agents' asymmetric information about current productivity. Crucially, incomplete yet symmetric information would have implied a neutral monetary policy.^{29,30}

A second remark is that the consumer's expectations about permanent productivity have real effects even though prices are flexible. To see this, note that the wedge in agents' expectations about stage-2 inflation, which appears on the RHS of (24), is equal to³¹

$$E_t^p[\pi_t] - E_t^c[\pi_t] = E_t^p[\pi_t] - \pi_t = [\kappa_2 k(1 - \theta) + \kappa_3](E_t^p[a_t] - a_t) . \quad (25)$$

The presence of the coefficient κ_2 in (25) attests that the consumer's expectations have real effects.

Once again, this is related to information heterogeneity but is not implied by it. This time we need a stronger assumption in place: the consumer needs to possess information about permanent productivity the producer does not. In our case, this extra information is current productivity, which serves as a private signal to the consumer. To the extent that inflation depends on the consumer's expectations about permanent productivity, as (C2) implies, and to the extent that the producer needs to guess inflation, as (24) shows, the producer needs to second-guess the consumer. It is then only via the inflation channel that the consumer's expectations matter.³² Further, we

²⁹This paper shares with, among others, Weiss (1980), King (1982), and Lorenzoni (2010) the insight that it is asymmetric, as opposed to incomplete yet symmetric, information about the monetary authority's future (here, stage-2) actions that breaks the policy irrelevance proposed in Sargent and Wallace (1975, 1976). Implicit in this argument is that the monetary authority is more informed (about inflation) at the time it steps in than the least informed of the agents (here, the producer) at the time the labor decision is made. This is true here since the time advantage of the monetary authority is essentially an informational advantage; in fact, the monetary authority perfectly observes or has extracted the variables in question (inflation, output, current productivity) when it steps in.

³⁰My focus throughout is on the business cycle effects of shocks to expectations be they purely expectational or productivity shocks. A perfectly legitimate, though, question, especially when it comes to monetary policy making, concerns the presence of indeterminacies. The answer here is that there is no real but there can be nominal indeterminacy. The latter refers to the possibility that inflation is susceptible to non-fundamental ("sunspot") shocks. However, "sunspot" shocks lie outside both agents' information sets at the time the labor decision is made; hence, they cannot have real effects. To rule out "sunspot" shocks, $\phi_\pi > 1$ suffices. But let me repeat that my focus is not on such considerations.

³¹Note, first, that $E_t^p[E_t^c[x_t]] = E_t^c[x_t] + k(1 - \theta)(E_t^p[a_t] - a_t)$ (see also (51) in Appendix A.2). Conjecture (C2) together with the fact that $E_t^c[\pi_t] = \pi_t$ leads to (25).

³²One could modify conjecture (C1) by allowing consumption to depend directly on the consumer's expectations only to verify that, in fact, the consumer's expectations do not enter equilibrium output directly (but only via inflation).

can see from (22) that $\kappa_2 = \frac{1}{\phi_\pi}$ which suggests that the way the consumer's expectations affect inflation is in turn controlled by the monetary authority.

Connecting the above remarks, what affects the labor decision—hence, the real side of the economy—via the inflation channel is the wedge in the agents's expectations about inflation, $E_t^p[\pi_t] - E_t^c[\pi_t]$: anything lying in the intersection of the agents' information sets (for example, the producer's expectations) and anything lying outside their union (possibly, non-fundamental shocks—see fn. 30 below) has no real effects through the inflation channel. It should perhaps come as no surprise then that, first, incomplete yet symmetric information about current productivity would have implied a neutral monetary policy; second, that the consumer's expectations would have had no real effects had they been contained within the producer's information set.

Let me conclude this part by taking a step back. The producer's expectations about productivity matter to the extent that the producer needs to guess his stage-2 revenue as his profit-maximization problem requires. The producer's expectations matter in three ways and enter the real side of the economy via two channels. The first way/channel is direct and the first term in (24) testifies to its presence: it is due to the producer's attempt to guess the quantity to be produced in stage 2 (quantity channel). The other two ways are via inflation and are due to the producer's attempt to guess the prices to prevail in stage 2. The first of the two is direct (via inflation), as the presence of κ_3 in (25) attests; the second one is indirect through the consumer's expectations, which I discussed above. The inflation channel is controlled by the monetary authority. This is exactly why monetary policy takes center stage in this paper. The next section demonstrates its role.

3.3.1 Demand or supply shocks?

I will first discuss purely expectational shocks. This will help us concentrate on the “mechanics” of agents' expectations. Let me first point out that (see also Appendix A.2)

$$\kappa_1 + \kappa_2 + \kappa_3 = 0 \tag{26}$$

$$\kappa_1 + \kappa_3 = -\frac{1}{\phi_\pi}. \tag{27}$$

Combining (26) and (27) implies $\kappa_2 = \frac{1}{\phi_\pi} > 0$, which we can also see from (22): the consumer's expectations are positively related to inflation. Consequently, indirectly through inflation they are positively related to output which we can see from (24) and (25). The underlying logic is a permanent income hypothesis one. To see this, consider with no loss of generality a positive purely

expectational shock: since a positive purely expectational shock leads the consumer to overstate the long-run prospects of the economy, consumption smoothing will result in a current demand increase which, in turn, will cause an inflationary pressure. Had the producer complete information about current productivity, nominal wages would proportionally adjust in stage 1 as demonstrated in Section 3.2 and no real effects would arise via the consumer channel. However, that is not the case under incomplete information: an overly optimistic producer—the public signal coordinates agents—overestimates the inflationary pressure. As a result, the nominal wage increases more than proportionally relative to prices. This, of course, implies that the real wage increases which causes labor to increase and production to expand, thereby partly accommodating the increased demand. In other words, purely expectational shocks operating via the consumer’s expectations channel push toward a demand shock interpretation.

Turning to the producer, (21) and (22) show that his expectations push output and inflation in opposite directions. A sufficient condition for the producer’s expectations to be positively related to output (hence, negatively related to inflation) is that

Condition 1. $\phi_\pi > \max\{\frac{\phi_y}{\zeta}, 1\}.$

Unless I state otherwise, you can assume that Condition 1 holds throughout the main text analysis (Appendix B characterizes all cases in detail). Condition 1 requires monetary policies to be sufficiently responsive to inflation.

For sufficiently “active” then policies, purely expectational shocks via the producer’s expectations push toward a co-monotone supply shock interpretation.³³ As I have already implied, the inefficiency caused due to the producer’s incomplete information manifests itself as a distortion in the labor optimality condition. In particular, it causes a shift in labor demand: the overly optimistic, for instance, expectations of the producer (a consequence of positive purely expectational shocks) will result in a higher real wage. This induces the worker to increase his labor supply and, consequently, production to expand. For a certain demand level, this causes a deflationary pressure:

³³ As I argued above, since the producer second-guesses the consumer when forming expectations about inflation, the consumer’s expectations matter indirectly as the term $\kappa_2 k(1 - \theta)$ in (25) shows. In fact, since $\kappa_2 > 0$, this term only accentuates the co-monotone supply-shock interpretation as (57) in Appendix A.2 shows. To disentangle the producer from the consumer channel, simply suppose that $\theta = 1$, which is the case when $\sigma_u^2 \rightarrow \infty$.

prices need to fall for the commodity market to clear.³⁴

Will a demand- or a supply-shock interpretation prevail for purely expectational shocks? Since both agents' expectations push employment and output in the same direction, the answer to this question will depend on whose effect on inflation dominates which, in turn, I will now argue depends on how monetary policy is pursued. To see the role of monetary policy, consider the limit case in which $\sigma_u^2 \rightarrow \infty$ which implies that $\theta = 1$ and $\kappa = \mu$. In this case, purely expectational shocks affect agents' expectations in exactly the same way and at all horizons.³⁵ Positive purely expectational shocks lower then inflation as long as $\kappa_1 + \kappa_2 < 0$ which at the same time is a sufficient condition for output to increase.³⁶ You can confirm from (26) and (27) that $\kappa_1 + \kappa_2 < 0$ is equivalent to requiring $\kappa_3 > 0$. For $\sigma_u^2 \rightarrow \infty$, confirm from (22) and (23) that κ_3 is given by

$$\kappa_3 = \frac{\phi_y - \zeta}{\phi_\pi (1 + \zeta) - (1 + \phi_y)}. \quad (28)$$

Maintaining Condition 1 implies that $\kappa_3 > 0$ if and only if $\phi_y > \zeta$. That is, a value of the monetary policy weight on the output gap, ϕ_y , greater than the inverse Frisch elasticity of labor supply, ζ , implies that purely expectational shocks are negatively related to inflation, featuring, therefore, a behavior akin to supply shocks. Further, the greater the weight on the output gap, the greater κ_3 is, and the more likely a supply-shock interpretation becomes.

To provide an intuition for this, first note that (22) implies expected inflation is zero, which, in turn, implies that the nominal and the real interest rates coincide:³⁷

$$r_t = i_t = \phi_\pi \pi_t + \phi_y (y_t - a_t). \quad (29)$$

Fix for a moment the real interest rate and consider a positive purely expectational shock. Following a positive purely expectational shock, both agents' expectations lead to a positive output gap; the

³⁴ For $\min\{\frac{1+\phi_y}{1+\zeta}, 1 - k(1 - \theta)\} < \phi_\pi < \max\{\frac{1+\phi_y}{1+\zeta}, 1 - k(1 - \theta)\}$, positive purely expectational shocks operating through the producer's expectations behave like negative supply shocks: they lower output and employment and they raise inflation. To see why, note first that, for appropriate values of the policy parameters ϕ_π, ϕ_y , inflation depends negatively on productivity, that is coefficient κ_3 becomes negative; in that case, the inflation wedge given by (25) falls in the producer's expectations. For the suggested parameter values, the negative effect arising via the inflation wedge outweighs the positive direct one, given by the first term in (24). As a result, the real wage falls relative to its complete information counterpart which induces the worker to decrease his labor supply and production to fall. Then, for the commodity market to clear prices need to rise.

³⁵ What is crucial is that the agents' learning coefficients are related in the following way: $k\theta = \mu$. This is a good approximation if the temporary productivity shock's variance is sufficiently small which is true for the parameters reported in Table 1 below (Appendix B considers all possibilities). Note further that by considering $\sigma_u^2 \rightarrow \infty$, which implies that $\theta = 1$, I essentially discard aggregate productivity as a signal about permanent productivity; therefore, I effectively mute the indirect via inflation effect of the consumer's expectations on output. Importantly though, the consumer's expectations' effect on inflation remains intact.

³⁶ To see this point, note that, since $\kappa_2 > 0$, $\kappa_1 + \kappa_2 < 0$ implies that $\kappa_1 < 0$ which in turn implies/requires $\xi_1 > 0$ (you can confirm this from (21) and (22)).

³⁷ For ease of exposition I have suppressed constants in (29) and (30).

greater the policy weight on it, the lower the inflationary pressure has to be for the real interest rate to remain constant. In this argument, however, I implicitly controlled for the size of the output gap increase; in fact, the greater ϕ_y , the greater ξ_1 and, thus, the greater the output gap increase, which provides further support to my argument.

Let me now allow for changes in the real interest rate in response to purely expectational shocks. The real interest rate is equal to

$$r_t = E_t^c [y_{t+1}] - y_t = E_t^c [x_t] - (\xi_1 E_t^p [a_t] + \xi_2 a_t). \quad (30)$$

The real interest rate increases in response to purely expectational shocks because expected future output increases by more than current output: current output is partly disciplined by current productivity whose long-run component agents overstate (you can confirm these from (30)). The greater the weight on the output gap, the lower the real interest increase.³⁸

Connecting the above remarks, to what extent or whether the real interest rate increase will be translated into higher inflation depends on the weight put on the (positive) output gap: the higher ϕ_y , the smaller the real interest rate increase, i.e. the lower the increase of the LHS of (29) will be, and the greater the output gap increase, i.e. the greater the increase of the last term on the RHS of (29) will be; therefore, the greater ϕ_y , the lower the inflationary pressure in response to positive purely expectational shocks will be which can actually turn negative (i.e. become a deflationary pressure) for ϕ_y greater than some threshold value ϕ_y^* which, in our case, is equal to ζ .

As Appendix B shows, the threshold value ϕ_y^* is always related to ζ . This is because ζ is equal to the inverse Frisch elasticity of labor supply: the lower ζ is, the more responsive labor supply becomes to changes in the real wage and, thus, to shocks to expectations.

Let me now turn to productivity shocks, in particular permanent ones.³⁹ The economy responds to them in an analogous way: Condition 1 is a sufficient one for positive permanent productivity shocks to raise output and lower employment; further, for $\phi_y > \zeta$, positive permanent productivity

³⁸Maintaining that purely expectational shocks affect agents' expectations in the same way, the response of the real interest rate following a positive purely expectational shock has the same sign as $1 - \xi_1$. That is positive since Condition 1 implies that $\xi_1 \in (0, 1)$. You can confirm using (23) that ξ_1 increases in ϕ_y (so $1 - \xi_1$ falls) which implies of course at the same time that the output gap increase in response to positive purely expectational shocks increases in ϕ_y .

³⁹Temporary productivity shocks cause on impact effects similar to those of permanent productivity shocks. From the following period onwards, they serve as purely expectational shocks. As their dynamic effects are a hybrid then of the two cases I analyze, I will not discuss them separately.

shocks raise inflation, whereas they lower inflation for $\phi_y < \zeta$.⁴⁰

To see the intuition and connect results with the previous analysis, consider a positive permanent productivity shock. Under complete information, as we saw in Section 3.2, inflation depends positively on the wedge between the consumer's expectations and productivity. Following a positive permanent productivity shock, the consumer's expectations underreact as the consumer attributes part of the increase in the public signal to its noise component; as a result, demand underreacts and prices fall so that the market clears. Yet, under incomplete information, prices do not fall as much as they would under complete information; in fact, they can even rise. This is because the producer's expectations underreact too, hence supply underreacts which pushes prices up. Both effects imply that output increases by less than it would under complete information which translates into a negative output gap and a fall in employment. Along the same lines as before, the response of inflation depends on whether the demand or supply effect dominates which in turn depends on the weight on the output gap: holding the real and, since they coincide, the nominal interest rate constant, the greater the weight on the (negative) output gap, the lower the real interest rate, hence the less the required fall in prices for the real interest rate to remain constant (see also (29)). However, both the nominal and the real interest rate fall after a positive permanent productivity shock, a consequence of the underreaction of expectations; yet, the greater the weight on the output gap, the less the real interest rate falls (see also (30) noting that ξ_2 decreases in ϕ_y).

By now, one might wonder what the role of the policy weight on inflation, ϕ_π , is. In fact, general equilibrium effects complicate matters considerably as both κ_2 and κ_3 (alternatively, κ_1) depend on ϕ_π . As a result, it is hard to apply a reasoning along the previous lines. Therefore, I have opted to abstract from such a consideration and to only require that monetary policy is sufficiently responsive to inflation as Condition 1 prescribes (for more details, once again you can turn to Appendix B).

Let me conclude this part by noting that when $E_t^p[a_t] = a_t$ the complete information equilibrium prevails.

3.3.2 Numerical examples

To illustrate my point, I will juxtapose two commonly considered pairs of monetary policy weights. The baseline parametrization is in Table 1 and is the same as in Lorenzoni (2009). This parametriza-

⁴⁰Juxtaposing this last result with the respective one above, it cannot be the case that permanent productivity and purely expectational shocks of the same sign have the same effect on inflation, which you can confirm from (26) and (27). Appendix B shows that this result holds for all values of σ_u .

Inverse Frisch elasticity of labor supply	ζ	0.5
Monetary policy weight on inflation	ϕ_π	1.5
Standard deviation of permanent productivity shock	σ_ϵ	0.0077
Standard deviation of temporary productivity shock	σ_u	0.15
Standard deviation of purely expectational shock	σ_e	0.03

Table 1: Parameters

tion implies that the Kalman gain terms, μ and k , are equal to 0.22 and 0.23, respectively, while the relative weight the consumer places on the public signal, θ , is equal to 0.96.

I assume that, before any shock hits, the economy is at its steady state. Since permanent productivity, x , evolves as a random walk (see (8)), the steady state is stochastic and is pinned down by x . For ease of exposition I will suppress constants; confirm then that, at the steady state, $y = c = x$, $n = 0$, $\pi = 0$, and $r = i = 0$.⁴¹ In all figures, impulse responses are for one-standard-deviation shocks; periods, which appear on the horizontal axis of the figures, should be interpreted as quarters. Further, with no loss of generality, I will assume that $x = 0$ before any shocks hit.⁴²

In Figures 3 and 5, I let $\phi_y = 0.5$ (as suggested in Taylor (1993)), whereas, in Figures 4 and 6, I let $\phi_y = 0$ (as in Lorenzoni (2009)). In line with the analysis in Section 3.3.1, what differentiates Figure 3 from Figure 4 and Figure 5 from Figure 6 is the response of inflation. In particular, in response to a positive purely expectational shock, inflation falls when $\phi_y = 0.5$ (Figure 3) and rises when $\phi_y = 0$ (Figure 4); in response to a positive permanent productivity shock, inflation rises when $\phi_y = 0.5$ (Figure 5) and falls when $\phi_y = 0$ (Figure 6). Further, observe that, since agents learn over time, the economy eventually returns to its initial steady state if a purely expectational shock hits (Figures 3 and 4), whereas it moves to its new steady state if a permanent productivity shock hits (Figures 5 and 6).

⁴¹The steady state of the economy, which is pinned down by the permanent (long-run) productivity component x , is conceptually different from its efficient, complete-information level which is pinned down by temporal aggregate productivity a_t . To see the connection between the two, note that when the economy is at its steady state, it is also at its complete-information level, since in the long run agents learn, but not vice versa. More precisely, the steady state requires that $a = x$ and $E^p[a] = E^c[x] = x$, whereas the complete-information equilibrium requires only that $E_t^p[a_t] = a_t$. When discussing impulse responses, I assume that, before any shocks hit, the economy has already reached its steady state which, based on the above, coincides with its complete information level. The two remain coincidental after a purely expectational or a permanent productivity shock hits, however they differ but only on impact after a temporary productivity shock hits.

⁴²A closed-form solution of the impulse response functions can easily be obtained.

4 Welfare

The consumer's lifetime utility is given by

$$W = \frac{1}{1-\beta} \left[\xi_0 - \frac{1}{1+\zeta} e^{(1+\zeta)\xi_0 + \frac{(1+\zeta)^2}{2} [(\mu-1)^2 \sigma_x^2 + \mu^2 \sigma_e^2 + \sigma_u^2] \xi_1^2} \right] + t.i.p. \quad (31)$$

Using (72), we can express ξ_0 and, thereby, W in terms of ξ_1 . We can then confirm that $d^2W/d\xi_1^2 < 0$ which implies that $dW/d\xi_1 = 0$ is a necessary and sufficient condition for a maximum. Maximum welfare is attained when $\xi_1 = 0$ (all derivations are collected in Appendix A.3), which renders the economy equivalent to the benchmark complete information economy (see Section 3.2). This should be rather unsurprising: since the producer's incomplete information is the only source of inefficiency,⁴³ optimal monetary policy should prevent producer expectations from having real effects.

Interestingly, in the limit case where $\phi_\pi \rightarrow \infty$, $\xi_1 \neq 0$. This proves inflation stabilization sub-optimal, a result at odds with Lorenzoni (2009).⁴⁴ As in Blanchard and Gali (2007) and the more related work by Angeletos and La'O (2012a), the presence of a real rigidity prevents inflation stabilization from leading to output gap stabilization (i.e. the so called "divine coincidence" breaks down). More intuitively, at the beginning of each period producers face uncertainty about their revenue in stage 2; by stabilizing inflation, a policy maker can only eliminate producers' uncertainty about the prices they (producers) will sell at in stage 2, while does nothing to ameliorate producers' uncertainty about the quantities to be produced.⁴⁵

Optimal monetary policy should manipulate inflation in a way such that producers, despite their uncertainty about productivity, correctly anticipate their stage-2 revenue. It turns out that setting $\phi_\pi = 1 - k(1 - \theta)$ achieves this for any value of ϕ_y .⁴⁶ This policy is though hardly realistic since it requires a monetary authority to be fully aware of the agents' learning problems let alone that it

⁴³One could argue that the inefficiency here is due to agents' asymmetric information; were agents to have incomplete yet symmetric information, optimality would be restored. This is true only because preferences are logarithmic in consumption; in more general environments, the producer's incomplete information would suffice. Nevertheless, it is asymmetric, rather than incomplete yet symmetric, information together with the presence of a nominal bond market that enables the monetary authority to drive the economy to its optimal level. Were a real bond market in lieu of the nominal bond market, the inflation channel would be absent and that would not be possible.

⁴⁴It is in fact at odds with any work drawing on the workhorse New Keynesian model as presented in Chapter 3 in Gali (2008).

⁴⁵Using the language of Section 3.3, stabilizing inflation eliminates uncertainty arising only via the inflation channel of expectations.

⁴⁶This implies that results in Section 3 are the outcome of suboptimal policies.

leads to nominal indeterminacy (see also fn. 30).

Interestingly, optimality is (also) restored in the limit when $\phi_y \rightarrow \infty$ for any value of ϕ_π ; being infinitely aggressive on the output gap prevents producer expectations from having real effects.⁴⁷ This result is also in sharp contrast with the policy implications of the New Keynesian paradigm (see Chapter 4 in Gali (2008)); in a sense, the conventional policy implications of the New Keynesian paradigm are here overturned: inflation stabilization is suboptimal, whereas output-gap stabilization is optimal.

I will conclude this section by discussing how changes in the policy parameters, ϕ_π and ϕ_y , affect welfare, with my attention restricted only to policies involving values of ϕ_π greater than one (again, check fn. 30). I will juxtapose the performance of different policies, pinned down by (ϕ_π, ϕ_y) , with that of the optimal ones with the comparison being in consumption terms.⁴⁸ I will in particular look for the value of Δ which is such that

$$W((1 + \Delta)C, N) = W^*(C, N), \quad (32)$$

where $W^*(\cdot)$ denotes the maximized welfare value, obtained for policies implying $\xi_1 = 0$. Figures 7 and 8 illustrate the welfare comparison.⁴⁹

To provide an algebraic account of the figures, let me first hold ϕ_y constant (Figure 7). For $\phi_y < \zeta - (1 + \zeta)k(1 - \theta)$ welfare decreases in ϕ_π , for $\phi_y \in [\zeta - (1 + \zeta)k(1 - \theta), \zeta]$ welfare (weakly) increases in ϕ_π , whereas for $\phi_y > \zeta$ welfare increases when $\phi_\pi > \frac{1+\phi_y}{1+\zeta}$ and decreases when $\phi_\pi < \frac{1+\phi_y}{1+\zeta}$.⁵⁰ Δ responds in the opposite direction which follows from (32).

Next, hold ϕ_π fixed (Figure 8). You can confirm that welfare decreases in ϕ_y when $\phi_y < (1 + \zeta)\phi_\pi - 1$ and increases when $\phi_y > (1 + \zeta)\phi_\pi - 1$.⁵¹

⁴⁷That would not be the case if a monetary authority was instead targeting output.

⁴⁸A similar exercise is done in Lorenzoni (2010).

⁴⁹Let me make four comments about Figures 7 and 8. First, in addition to the values of the non-policy parameters which can be found in Table 1, I set $\beta = 0.99$. Second, the values of Δ , which appear on the vertical axis, are multiplied by 100 so that the consumption change corresponding to a welfare difference is expressed in percentage points. Third, for expositional reasons I do not report values of Δ greater than 5 percentage points; instead, I report 5. I do so because, around the discontinuity point, Δ takes very large positive values tending to infinity. Fourth, the “step” for ϕ_π in Figure 7 and ϕ_y in Figure 8 is 0.1.

⁵⁰Maintaining first that $\phi_\pi > 1$, we can see from (23) that $\xi_1 > 0$ as long as $\phi_\pi > \max\{1, \frac{1+\phi_y}{1+\zeta}\}$. Differentiating ξ_1 with respect to ϕ_π yields $\frac{\zeta - \phi_y - (1+\zeta)k(1-\theta)}{[\phi_\pi(1+\zeta) - (1+\phi_y)]^2}$ which is negative as long as $\phi_y > \zeta - (1 + \zeta)k(1 - \theta)$. Remarks in the main text follow after further taking into account that $d^2W/d\xi_1^2 < 0$ and $\frac{dW}{d\xi_1}|_{\xi_1=0} = 0$. Last, note that ξ_1 and $\partial \xi_1 / \partial \phi_\pi$ exhibit a discontinuity when $\phi_\pi = \frac{1+\phi_y}{1+\zeta}$.

⁵¹Maintaining that $\phi_\pi > 1$, confirm that $\partial \xi_1 / \partial \phi_y > 0$. That means that whether welfare increases or decreases in ϕ_y depends solely on the sign of ξ_1 , hence the remarks in the main text. Once again, note that there is a discontinuity when $\phi_y = (1 + \zeta)\phi_\pi - 1$ (equivalently, when $\phi_\pi = \frac{1+\phi_y}{1+\zeta}$).

5 Conclusion

This paper has reconsidered the behavior of purely expectational shocks within a competitive, cashless, monetary economy. Asymmetric information about fundamentals is the driving force in the model since it leads agents to form heterogeneous expectations about inflation. As a result, monetary policy and consumer expectations have real effects via the inflation channel. Traditionally, purely expectational shocks are thought to behave like Keynesian demand shocks: when positive, they increase output, employment and inflation. I have shown that such an interpretation remains possible but is not the only one. Purely expectational shocks can cause business cycle patterns associated with supply shocks: when positive, they increase output and employment yet they lower inflation. Such an interpretation seems in line with the low inflation and the high cyclical employment in the US in the second half of the 90s, a period of exuberant optimism. Whether purely expectational shocks manifest themselves as demand or supply shocks reflects the monetary policy pursued. And it is precisely this the message this paper bears.

On the policy front, I have shown that traditional monetary policy recommendations are overturned. Optimal monetary policies need to manipulate inflation in a way such that the producer correctly anticipates his revenue. Inflation stabilization fails to do so since it can only eliminate uncertainty about prices while does nothing to ameliorate uncertainty about the quantities to be sold. On the contrary, output-gap stabilization restores optimality: expecting the monetary authority to respond infinitely aggressively to possible deviations of output from its natural level eventually renders expectations irrelevant.

On the empirical front, recovering purely expectational shocks from the data would in fact shed light on their seemingly shifting nature. Of course, the literature on the identification of purely expectational shocks remains far from settled (for example, [Beaudry and Portier \(2006\)](#), [Blanchard et al. \(2012\)](#) and [Barsky and Sims \(2012, 2011\)](#)). Further, studying the effects of purely expectational shocks in an environment enriched with credit constraints is a rather natural extension not least for the monetary policy implications it would generate. But I shall leave these for future work.

A Omitted derivations

A.1 Kalman filter

Let me start with the consumer's case which is easier to handle. Suppose that the consumer's prior for period- t permanent productivity, x_t , is

$$x_t | I_{t-1}^c \sim N(x_{t|t-1}, \sigma_{x,t-1}^2),$$

where $x_{t|t-1} = E[x_t | I_{t-1}^c]$ and $\sigma_{x,t-1}^2 \equiv \text{Var}[x_t | I_{t-1}^c]$.

Upon the arrival of new information, $\{s_t, a_t\}$, the consumer's information set becomes $I_t^c = I_{t-1}^c \cup \{s_t, a_t\}$. Taking into account that all shocks are serially uncorrelated, mutually independent, and normally distributed and using Bayes' Law implies that the consumer's posterior distribution is

$$x_t | I_t^c \sim N \left((1 - k_t) x_{t|t-1} + k_t [\theta s_t + (1 - \theta) a_t], \left(\frac{1}{\sigma_{x,t-1}^2} + \frac{1}{\sigma_e^2} + \frac{1}{\sigma_u^2} \right)^{-1} \right),$$

where $k_t \equiv \frac{\frac{1}{\sigma_e^2} + \frac{1}{\sigma_u^2}}{\frac{1}{\sigma_{x,t-1}^2} + \frac{1}{\sigma_e^2} + \frac{1}{\sigma_u^2}}$ and $\theta \equiv \frac{\frac{1}{\sigma_e^2}}{\frac{1}{\sigma_e^2} + \frac{1}{\sigma_u^2}}$. The former denotes the Kalman gain term, that is the precision of new information, $\{s_t, a_t\}$, relative to the total precision of the consumer's information; the latter denotes the precision of the signal s_t relative to that of the consumer's new information.

Letting $\sigma_{x,t}^2 \equiv \text{Var}[x_{t+1} | I_t^c]$, the following period's prior is

$$x_{t+1} | I_t^c \sim N(x_{t+1|t}, \sigma_{x,t}^2),$$

where $x_{t+1|t} = (1 - k_t) x_{t|t-1} + k_t [\theta s_t + (1 - \theta) a_t]$ and

$$\sigma_{x,t}^2 = \left(\frac{1}{\sigma_{x,t-1}^2} + \frac{1}{\sigma_e^2} + \frac{1}{\sigma_u^2} \right)^{-1} + \sigma_e^2. \quad (33)$$

Let σ_x^2 denote the solution (a fixed point) to the Riccati equation (33) (simply set $\sigma_x^2 \equiv \sigma_{x,t-1}^2 = \sigma_{x,t}^2$). A solution does not exist in the limit case where $\sigma_e^2 \rightarrow \infty$ and $\sigma_u^2 \rightarrow \infty$ which I therefore dismiss.

I assume that both agents' prior in period 0 is $x_{0|-1} \sim N(0, \sigma_x^2)$, which implies that their learning problems (see below for the producer) are at their steady state when time commences. As a result, the Kalman gain term in (20) is time invariant and given by

$$k \equiv \frac{\frac{1}{\sigma_e^2} + \frac{1}{\sigma_u^2}}{\frac{1}{\sigma_x^2} + \frac{1}{\sigma_e^2} + \frac{1}{\sigma_u^2}}.$$

Turning to the producer's learning problem, recall from the main text analysis that, by the end of each period, both agents have received the same new information. Given their (assumed to be) common prior in period 0, this implies that at the end of each period $I_{t-1,2}^p = I_{t-1}^c$. As a result, agents always have the same prior distribution over the following period's x , which is time invariant as long as σ_x^2 solves the Riccati equation (33).

The consumer and the producer's information sets differ though in stage 1 of each period. In particular, the producer's information set is $I_{t,1}^p = I_{t-1,2}^p \cup \{s_t\}$. Then,

$$x_t | I_{t,1}^p \sim N \left((1 - \mu_t) x_{t|t-1} + \mu_t s_t, \left(\frac{1}{\sigma_{x,t-1}^2} + \frac{1}{\sigma_e^2} \right)^{-1} \right),$$

where $\mu_t \equiv \frac{\frac{1}{\sigma_e^2}}{\frac{1}{\sigma_{x,t-1}^2} + \frac{1}{\sigma_e^2}}$. To the extent that σ_x^2 is time invariant, μ_t is also time invariant and given by $\mu \equiv \frac{\frac{1}{\sigma_e^2}}{\frac{1}{\sigma_x^2} + \frac{1}{\sigma_e^2}}$, which is the coefficient in (19).

Along the same lines and using (7), we can characterize the evolution of the producer's distribution of aggregate productivity, a , over time:

$$a_t | I_{t-1,2}^p \sim N(x_{t|t-1}, \sigma_{x,t-1}^2 + \sigma_u^2) \quad (34)$$

$$a_t | I_{t,1}^p \sim N \left((1 - \mu_t) x_{t|t-1} + \mu_t s_t, \left(\frac{1}{\sigma_{x,t-1}^2} + \frac{1}{\sigma_e^2} \right)^{-1} + \sigma_u^2 \right) \quad (35)$$

$$a_{t+1} | I_{t,2}^p \sim N(x_{t+1|t}, \sigma_{x,t}^2 + \sigma_u^2). \quad (36)$$

Once again, as long as σ_x^2 solves (33), the variance of the producer's (prior or posterior) distribution for a is also time invariant (for instance, in the case of the producer's prior simply juxtapose (34) and (36)).

A thorough demonstration of the Kalman filter can be found in [Anderson and Moore \(1979\)](#), [Harvey \(1989\)](#), and Technical Appendix B in [Ljungqvist and Sargent \(2004\)](#).

A.2 Equilibrium

A.2.1 Complete information

Under complete information $Y_t = A_t$, which you can confirm from (10) and (12). This implies that the Euler equation (18) becomes

$$\Pi_t^- \phi_\pi = E_t^c \left[\frac{1}{\Pi_{t+1}} \frac{A_t}{A_{t+1}} \right]. \quad (37)$$

Conjecture that $\pi_t = \vartheta_0 + \vartheta_1 E_t^c [x_t] + \vartheta_2 a_t$.

Given this conjecture, the LHS of (37) is equal to

$$e^{-\phi_\pi (\vartheta_0 + \vartheta_1 E_t^c [x_t] + \vartheta_2 a_t)}. \quad (38)$$

Turning to the RHS of (37), first confirm that

$$E_t^c [\pi_{t+1} + a_{t+1}] = \vartheta_0 + (\vartheta_1 + \vartheta_2 + 1) E_t^c [x_t]$$

$$Var_t^c [\pi_{t+1} + a_{t+1}] = (\vartheta_1 k + \vartheta_2 + 1)^2 \sigma_x^2 + (\vartheta_1 k \theta)^2 \sigma_e^2 + [\vartheta_1 k (1 - \theta) + \vartheta_2 + 1]^2 \sigma_u^2.$$

The RHS of (37) is then equal to

$$e^{-[\vartheta_0 + (\vartheta_1 + \vartheta_2 + 1) E_t^c [x_t]] + a_t + \frac{1}{2} \{(\vartheta_1 k + \vartheta_2 + 1)^2 \sigma_x^2 + (\vartheta_1 k \theta)^2 \sigma_e^2 + [\vartheta_1 k (1 - \theta) + \vartheta_2 + 1]^2 \sigma_u^2\}}. \quad (39)$$

Matching coefficients in (38) and (39) yields

$$-\phi_\pi \vartheta_1 = -(\vartheta_1 + \vartheta_2 + 1) \quad (40)$$

$$-\phi_\pi \vartheta_2 = 1 \quad (41)$$

$$-\phi_\pi \vartheta_0 = -\vartheta_0 + \frac{1}{2} \{(\vartheta_1 k + \vartheta_2 + 1)^2 \sigma_x^2 + (\vartheta_1 k \theta)^2 \sigma_e^2 + [\vartheta_1 k (1 - \theta) + \vartheta_2 + 1]^2 \sigma_u^2\}. \quad (42)$$

Solving (40)-(42) yields $\vartheta_1 = \frac{1}{\phi_\pi}$, $\vartheta_2 = -\frac{1}{\phi_\pi}$, and

$$\vartheta_0 = -\frac{1}{2(\phi_\pi - 1)} \{(\vartheta_1 k + \vartheta_2 + 1)^2 \sigma_x^2 + (\vartheta_1 k \theta)^2 \sigma_e^2 + [\vartheta_1 k (1 - \theta) + \vartheta_2 + 1]^2 \sigma_u^2\}. \quad (43)$$

A.2.2 Incomplete information

Let me start with the optimality conditions. Plug the producer's labor demand condition, (12), into the consumer's labor supply condition, (10), replace for λ_t taking into account that $\lambda_t = \frac{1}{P_t C_t}$, multiply and divide the RHS of the generated expression by P_{t-1} , and confirm that

$$N_t^\zeta = \frac{1}{\Pi_t C_t} \frac{E_t^p \left[\frac{A_t}{C_t} \right]}{E_t^p \left[\frac{1}{\Pi_t C_t} \right]}. \quad (44)$$

Turning to the Euler equation, (11), take into account that the monetary authority sets the nominal bond price according to (6), and confirm that

$$\Pi_t^{-\phi_\pi} \left(\frac{Y_t}{Y_t^*} \right)^{-\phi_y} = E_t^c \left[\frac{1}{\Pi_{t+1}} \frac{C_t}{C_{t+1}} \right]. \quad (45)$$

Note that (44) and (45) correspond to (17) and (18), respectively. Further, it follows from Section 3.2 that $Y_t^* = A_t$ which I will use from now on.

Let me now post the following conjectures for log-consumption and log-inflation:

$$c_t = \xi_0 + \xi_1 E_t^p[a_t] + \xi_2 a_t \quad (C1')$$

$$\pi_t = \kappa_0 + \kappa_1 E_t^p[a_t] + \kappa_2 E_t^c[x_t] + \kappa_3 a_t. \quad (C2')$$

Relative to (C1) and (C2), conjectures (C1') and (C2') allow for constant terms.

Given that all shocks are normally distributed, I will show that, conditional on the agents' information sets, conjectures (C1') and (C2') imply that C_t and Π_t are log-normally distributed.

Let me start with the labor optimality condition, (44). Take technology (in logs $y_t = a_t + n_t$) into account and express it as follows:

$$e^{\zeta(y_t - a_t)} = e^{-(\pi_t + c_t)} \frac{E_t^p[e^{a_t - c_t}]}{E_t^p[e^{-(\pi_t + c_t)}]}. \quad (46)$$

Next, use market clearing, rearrange terms in (46), and confirm that

$$e^{(1+\zeta)c_t - \zeta a_t + \pi_t} = \frac{E_t^p[e^{a_t - c_t}]}{E_t^p[e^{-(\pi_t + c_t)}]}. \quad (47)$$

Taking conjectures (C1') and (C2') into account, the LHS of (47) is equal to

$$e^{(1+\zeta)\xi_0 + \kappa_0 + [(1+\zeta)\xi_1 + \kappa_1] E_t^p[a_t] + \kappa_2 E_t^c[x_t] + [(1+\zeta)\xi_2 - \zeta + \kappa_3] a_t}. \quad (48)$$

The RHS of (47) is equal to

$$\frac{E_t^p [e^{-\xi_0 - \xi_1 E_t^p [a_t] + (1 - \xi_2) a_t}]}{E_t^p [e^{-\{\kappa_0 + \xi_0 + (\kappa_1 + \xi_1) E_t^p [a_t] + \kappa_2 E_t^c [x_t] + (\kappa_3 + \xi_2) a_t\}}]} . \quad (49)$$

Conditional on the producer's information set, $I_{t,1}^p = \Psi_t \setminus \{a_t\}$, the exponent in the nominator of (49) is normally distributed with mean $-\xi_0 + (1 - \xi_1 - \xi_2) E_t^p [a_t]$ and variance $(1 - \xi_2)^2 \sigma_{p,a}^2$, where $\sigma_{p,a}^2 \equiv \text{Var} [a_t | I_{t,1}^p] = \left(\frac{1}{\sigma_x^2} + \frac{1}{\sigma_e^2} \right)^{-1} + \sigma_u^2$ with σ_x^2 solving the Riccati equation (33) (see also the analysis in A.1). Then, the nominator of (49) is equal to

$$e^{-\xi_0 + (1 - \xi_1 - \xi_2) E_t^p [a_t] + \frac{1}{2} (1 - \xi_2)^2 \sigma_{p,a}^2} . \quad (50)$$

Before turning to the denominator of (49), note that it follows from (19) and (20) that

$$E_t^p [E_t^c [x_t]] = (1 - k) E_{t-1}^c [x_{t-1}] + k [\theta s_t + (1 - \theta) E_t^p [a_t]] = E_t^c [x_t] + k (1 - \theta) (E_t^p [a_t] - a_t) . \quad (51)$$

Let me now turn to the exponent in the denominator of (49). It is normally distributed and, using (51), its mean is equal to

$$E_t^p [-(\pi_t + c_t)] = -\{\kappa_0 + \xi_0 + [\kappa_1 + \kappa_2 k (1 - \theta) + \kappa_3 + \xi_1 + \xi_2] E_t^p [a_t] + \kappa_2 E_t^c [x_t] - \kappa_2 k (1 - \theta) a_t\} . \quad (52)$$

To find its variance, $\text{Var}_t^p [-(\pi_t + c_t)]$, where $\text{Var}_t^p [\cdot] \equiv \text{Var} [\cdot | I_{t,1}^p]$, first bring $\pi_t + c_t$ into the following form:

$$\pi_t + c_t = \kappa_0 + \xi_0 + (\kappa_1 + \xi_1) E_t^p [a_t] + \kappa_2 [(1 - k) E_{t-1}^c [x_{t-1}] + k \theta s_t] + [\kappa_2 k (1 - \theta) + \kappa_3 + \xi_2] a_t .$$

It then follows that

$$\text{Var}_t^p [-(\pi_t + c_t)] = [\kappa_2 k (1 - \theta) + \kappa_3 + \xi_2]^2 \sigma_{p,a}^2 . \quad (53)$$

Using (52) and (53), the denominator on the RHS of (49) is then equal to

$$E_t^p [e^{-(\pi_t + c_t)}] = e^{-\{\kappa_0 + \xi_0 + [\kappa_1 + \kappa_2 k (1 - \theta) + \kappa_3 + \xi_1 + \xi_2] E_t^p [a_t] + \kappa_2 E_t^c [x_t] - \kappa_2 k (1 - \theta) a_t\} + \frac{1}{2} [\kappa_2 k (1 - \theta) + \kappa_3 + \xi_2]^2 \sigma_{p,a}^2} . \quad (54)$$

Therefore, the RHS of (49) is equal to (simply divide (50) by (54))

$$e^{\kappa_0 + \frac{1}{2} \{(1 - \xi_2)^2 - [\kappa_2 k (1 - \theta) + \kappa_3 + \xi_2]^2\} \sigma_{p,a}^2 + [1 + \kappa_1 + \kappa_2 k (1 - \theta) + \kappa_3] E_t^p [a_t] + \kappa_2 E_t^c [x_t] - \kappa_2 k (1 - \theta) a_t} . \quad (55)$$

Matching coefficients in (48) and (55) yields

$$\xi_0 = \frac{1}{2(1+\zeta)} \{(1-\xi_2)^2 - [\kappa_2 k(1-\theta) + \kappa_3 + \xi_2]^2\} \sigma_{p,a}^2 \quad (56)$$

$$\xi_1 = \frac{1 + \kappa_2 k(1-\theta) + \kappa_3}{1 + \zeta} \quad (57)$$

$$\xi_2 = \frac{\zeta - \kappa_2 k(1-\theta) - \kappa_3}{1 + \zeta}. \quad (58)$$

Observe that

$$\xi_1 + \xi_2 = 1, \quad (59)$$

a direct consequence of preferences logarithmic in consumption.

Turning to the Euler equation, (45), it can be expressed as follows:

$$e^{-[\phi_\pi \pi_t + \phi_y (y_t - a_t)]} = e^{c_t} E_t^c [e^{-(c_{t+1} + \pi_{t+1})}]. \quad (60)$$

Let me start with the LHS of (60). We can use market clearing and conjectures (C1') and (C2') to express it as

$$e^{-[\phi_\pi \pi_t + \phi_y (y_t - a_t)]} = e^{-\{\phi_\pi \kappa_0 + \phi_y \xi_0 + (\phi_\pi \kappa_1 + \phi_y \xi_1) E_t^p [a_t] + \phi_\pi \kappa_2 E_t^c [x_t] + [\phi_\pi \kappa_3 + \phi_y (\xi_2 - 1)] a_t\}}. \quad (61)$$

Before continuing, note that

$$E_t^c [E_{t+1}^p [a_{t+1}]] = E_t^c [x_t], \quad (62)$$

which in turn follows from (19) and (20).

Turning now to the RHS of (60), $c_{t+1} + \pi_{t+1}$ conditional on the consumer's information set, $I_t^c = \Psi_t$, is normally distributed with mean

$$E_t^c [c_{t+1} + \pi_{t+1}] = \xi_0 + \kappa_0 + (\xi_1 + \xi_2 + \kappa_1 + \kappa_2 + \kappa_3) E_t^c [x_t], \quad (63)$$

where I have used conjectures (C1')-(C2') and (62).

To find the variance, $Var_{t+1}^c [c_{t+1} + \pi_{t+1}]$, where $Var_t^c [\cdot] \equiv Var[\cdot | I_t^c]$, express, first, $c_{t+1} + \pi_{t+1}$

as

$$c_{t+1} + \pi_{t+1} =$$

$$= \xi_0 + \kappa_0 + [(\xi_1 + \kappa_1)(1 - \mu) + \kappa_2(1 - k)] E_t^c [x_t] + [(\xi_1 + \kappa_1)\mu + \kappa_2 k \theta] s_{t+1} + [\xi_2 + \kappa_3 + \kappa_2 k (1 - \theta)] a_{t+1}$$

$$= G + [(\xi_1 + \kappa_1)\mu + \kappa_2 k + \xi_2 + \kappa_3] x_{t+1} + [(\xi_1 + \kappa_1)\mu + \kappa_2 k \theta] e_{t+1} + [\xi_2 + \kappa_3 + \kappa_2 k (1 - \theta)] u_{t+1},$$

where $G \equiv \xi_0 + \kappa_0 + [(\xi_1 + \kappa_1)(1 - \mu) + \kappa_2(1 - k)] E_t^c [x_t]$ is a known term to the consumer in period t .

Given that shocks are mutually independent, it follows that

$$Var_{t+1}^c [c_{t+1} + \pi_{t+1}] = [(\xi_1 + \kappa_1)\mu + \kappa_2 k + \xi_2 + \kappa_3]^2 \sigma_x^2 + [(\xi_1 + \kappa_1)\mu + \kappa_2 k \theta]^2 \sigma_e^2 + [\xi_2 + \kappa_3 + \kappa_2 k (1 - \theta)]^2 \sigma_u^2. \quad (64)$$

Hence, using (63) and (64) we can get that

$$E_t^c [e^{-(c_{t+1} + \pi_{t+1})}] =$$

$$= e^{-[\xi_0 + \kappa_0 + (\xi_1 + \xi_2 + \kappa_1 + \kappa_2 + \kappa_3) E_t^c [x_t]] + \frac{1}{2} \{[(\xi_1 + \kappa_1)\mu + \kappa_2 k + \xi_2 + \kappa_3]^2 \sigma_x^2 + [(\xi_1 + \kappa_1)\mu + \kappa_2 k \theta]^2 \sigma_e^2 + [\xi_2 + \kappa_3 + \kappa_2 k (1 - \theta)]^2 \sigma_u^2\}}.$$

Consequently, the RHS of (60) becomes

$$e^{c_t} E_t^c [e^{-(c_{t+1} + \pi_{t+1})}] = e^{-\kappa_0 + \frac{1}{2} \{[(\xi_1 + \kappa_1)\mu + \kappa_2 k + \xi_2 + \kappa_3]^2 \sigma_x^2 + [(\xi_1 + \kappa_1)\mu + \kappa_2 k \theta]^2 \sigma_e^2 + [\xi_2 + \kappa_3 + \kappa_2 k (1 - \theta)]^2 \sigma_u^2\}} \times e^{\xi_1 E_t^p [a_t] - (\xi_1 + \xi_2 + \kappa_1 + \kappa_2 + \kappa_3) E_t^c [x_t] + \xi_2 a_t}. \quad (65)$$

Matching coefficients in (61) and (65) yields

$$\kappa_0 = -\frac{\phi_y \xi_0 + \frac{1}{2} \{[(\xi_1 + \kappa_1)\mu + \kappa_2 k + \xi_2 + \kappa_3]^2 \sigma_x^2 + [(\xi_1 + \kappa_1)\mu + \kappa_2 k \theta]^2 \sigma_e^2 + [\xi_2 + \kappa_3 + \kappa_2 k (1 - \theta)]^2 \sigma_u^2\}}{\phi_\pi - 1} \quad (66)$$

and

$$-\xi_1 = \phi_y \xi_1 + \phi_\pi \kappa_1 \quad (67)$$

$$\xi_1 + \xi_2 = -\kappa_1 + (\phi_\pi - 1) \kappa_2 - \kappa_3 \quad (68)$$

$$-\xi_2 = \phi_y \xi_2 + \phi_\pi \kappa_3 - \phi_y, \quad (69)$$

where ξ_0 is given by (56), whereas $\xi_1, \xi_2, \kappa_1, \kappa_2, \kappa_3$ solve (58), (59) and (67)-(69) returning (21)-(23) in the main text.

Summing (67)-(69) across sides and using (59) yields

$$\kappa_1 + \kappa_2 + \kappa_3 = 0, \quad (70)$$

whereas summing (67) and (69) across sides and again using (59) yields

$$\kappa_1 + \kappa_3 = -\frac{1}{\phi_\pi}, \quad (71)$$

which are equations (26) and (27), respectively, in the main text.

Finally, use (59) and (67)-(69) and, after some manipulation, confirm that (56) can be expressed as

$$\xi_0 = \frac{(1 - \zeta) \sigma_{p,a}^2}{2} \xi_1^2. \quad (72)$$

We can, of course, express κ_0 in terms of ξ_1 by plugging (72) into (66).

A.3 Welfare

The expected lifetime utility of the consumer is given by

$$W(C, N) \equiv E_{-1}^c \sum_{t=0}^{\infty} \beta^t [\log C_t - \frac{1}{1+\zeta} N_t^{1+\zeta}]. \quad (73)$$

Let me first take the expectation of period- t utility conditional on the consumer's information set in period $t-1$. Using (59) and bearing in mind that $E_{t-1}^c[x_t] = E_{t-1}^c[x_{t-1}]$, confirm that

$$E[c_t | I_{t-1}^c] = \xi_0 + E_{t-1}^c[x_{t-1}]. \quad (74)$$

Turning to employment, first express it as

$$n_t = \xi_0 + \xi_1 (E_t^p [a_t] - a_t) = \xi_0 + \xi_1 (1 - \mu) E_{t-1}^c [x_{t-1}] + \xi_1 (\mu - 1) x_t + \xi_1 \mu e_t - \xi_1 u_t. \quad (75)$$

Given that shocks are mutually independent, employment is conditionally distributed as

$$n_t | I_{t-1}^c \sim (\xi_0, [(\mu - 1)^2 \sigma_x^2 + \mu^2 \sigma_e^2 + \sigma_u^2] \xi_1^2),$$

where σ_x^2 solves the Riccati equation (33).

It follows then that

$$E^c [\log C_t - \frac{1}{1+\zeta} N_t^{1+\zeta} | I_{t-1}^c] = \xi_0 + E_{t-1}^c [x_{t-1}] - \frac{1}{1+\zeta} e^{(1+\zeta)\xi_0 + \frac{(1+\zeta)^2}{2} [(\mu-1)^2 \sigma_x^2 + \mu^2 \sigma_e^2 + \sigma_u^2] \xi_1^2}. \quad (76)$$

To find unconditional expected utility (eq. (31) in the main text), use (76) noting that the second term on its RHS is independent of policy.

Combining (31) with (32) implies that Δ solves the following equation:

$$\log(1 + \Delta) = (\xi_0^* - \xi_0) - \frac{e^{(1+\zeta)\xi_0^* + \frac{(1+\zeta)^2}{2} [(\mu-1)^2 \sigma_x^2 + \mu^2 \sigma_e^2 + \sigma_u^2] \xi_1^{*2}} - e^{(1+\zeta)\xi_0 + \frac{(1+\zeta)^2}{2} [(\mu-1)^2 \sigma_x^2 + \mu^2 \sigma_e^2 + \sigma_u^2] \xi_1^2}}{1 + \zeta}, \quad (77)$$

where ξ_0^* and ξ_1^* denote the values of ξ_0 and ξ_1 that welfare-maximizing policies imply.

Let me now show that $dW/d\xi_1 = 0$ for $\xi_1 = 0$. First, use (72) to express W , given by (31), as a function of ξ_1 ; next, let $\gamma \equiv (\mu - 1)^2 \sigma_x^2 + \mu^2 \sigma_e^2 + \sigma_u^2$ and take the derivative of the resulting expression with respect to ξ_1 . That is equal to

$$\frac{dW}{d\xi_1} = \frac{\xi_1}{1 - \beta} \{ (1 - \zeta) \sigma_{p,a}^2 - e^{\frac{1+\zeta}{2} [(1-\zeta) \sigma_{p,a}^2 + \gamma(1+\zeta)]} \xi_1^2 [(1 - \zeta) \sigma_{p,a}^2 + \gamma(1 + \zeta)] \}. \quad (78)$$

For $\frac{dW}{d\xi_1} = 0$, it either has to be that $\xi_1 = 0$ or

$$\xi_1^2 = \frac{2}{(1 + \zeta) [(1 - \zeta) \sigma_{p,a}^2 + \gamma(1 + \zeta)]} \log \left[\frac{(1 - \zeta) \sigma_{p,a}^2}{(1 - \zeta) \sigma_{p,a}^2 + \gamma(1 + \zeta)} \right]. \quad (79)$$

You can confirm that the RHS of (79) is always a negative number. Since my focus is on real solutions, the only real one is then $\xi_1 = 0$.

The second-order derivative is equal to

$$\frac{d^2W}{d\xi_1^2} = \frac{1}{1 - \beta} \{ (1 - \zeta) \sigma_{p,a}^2 - e^{\frac{1+\zeta}{2} [(1-\zeta) \sigma_{p,a}^2 + \gamma(1+\zeta)]} \xi_1^2 [(1 - \zeta) \sigma_{p,a}^2 + \gamma(1 + \zeta)] \{ 1 + (1 + \zeta) \xi_1^2 [(1 - \zeta) \sigma_{p,a}^2 + \gamma(1 + \zeta)] \} \}, \quad (80)$$

which is always negative. It then follows that $\xi_1 = 0$ maximizes welfare. As a result, $\xi_0^* = \xi_1^* = 0$; plugging these values in (31) and (77) yields, respectively,

$$W^* = -\frac{1}{(1-\beta)(1+\zeta)} + t.i.p. \quad (81)$$

$$\log(1+\Delta) = -\xi_0 - \frac{1 - e^{(1+\zeta)\xi_0 + \frac{(1+\zeta)^2}{2}[(\mu-1)^2\sigma_x^2 + \mu^2\sigma_e^2 + \sigma_u^2]}\xi_1^2}{1+\zeta}. \quad (82)$$

B Appendix to Section 3.3 [incomplete]

In this Section I characterize the conditions which pin down the business cycle effects of purely expectational and productivity shocks.

B.1 Purely expectational shocks

Purely expectational shocks cause on *impact* effects associated with (co-monotone) supply shocks—that is when positive, they increase output and employment and they lower inflation—when

$$\xi_1 > 0 \quad (A)$$

$$(1 + \phi_y)\xi_1\mu - k\theta > 0, \quad (B)$$

where ξ_1 is given by (23). To see this, check (21), (22) and (19), (20).

Purely expectational shocks cause post-impact effects associated with supply effects when condition A holds, whereas the counterpart of B is

$$(1-\mu)(1-k)^{\tau-1}k\theta + (1-k)^\tau k\theta > 0, \text{ for } \tau \geq 1.$$

In fact, one can confirm from Section A.1 that $\frac{1-\mu}{1-k} = \frac{\mu}{k\theta}$. Hence, conditions A and B are sufficient for purely expectational shocks to cause effects over time associated with supply shocks.

Rearranging terms in B yields

$$\xi_1 > \frac{1}{1+\phi_y} \frac{1-k}{1-\mu}.$$

Notice that the term on the RHS is positive since by assumption k, θ, μ are positive and ϕ_y non-negative. As a result, B implies A. Condition B is then necessary and sufficient for purely

expectational shocks to behave like supply shocks. One can confirm that condition [B](#) boils down to the following requirements:

$$\phi_y > \frac{1-k}{1-\mu} (1+\zeta) - 1 \quad \text{and} \quad \phi_\pi > \frac{1+\phi_y}{1+\zeta} \quad (83)$$

or

$$\phi_y < \frac{1-k}{1-\mu} (1+\zeta) - 1 \quad \text{and} \quad \phi_\pi < \frac{1+\phi_y}{1+\zeta}. \quad (84)$$

Along the same lines, purely expectational shocks cause effects associated with demand shocks—that is when positive, they increase output, employment and inflation—when

$$\xi_1 > 0 \quad (\text{A})$$

$$(1 + \phi_y) \xi_1 \mu - k \theta < 0, \quad (\text{C})$$

with ξ_1 given by [\(23\)](#).

Confirm that $\frac{1-k}{1-\mu} = 1 - k(1 - \theta) = \frac{k\theta}{\mu}$. Condition [A](#) requires

$$\phi_\pi > \max \left\{ \frac{1+\phi_y}{1+\zeta}, \frac{1-k}{1-\mu} \right\} \quad (85)$$

or

$$\phi_\pi < \min \left\{ \frac{1+\phi_y}{1+\zeta}, \frac{1-k}{1-\mu} \right\}. \quad (86)$$

Condition [C](#) requires

$$\phi_y > \frac{1-k}{1-\mu} (1+\zeta) - 1 \quad \text{and} \quad \phi_\pi < \frac{1+\phi_y}{1+\zeta} \quad (87)$$

or

$$\phi_y < \frac{1-k}{1-\mu} (1+\zeta) - 1 \quad \text{and} \quad \phi_\pi > \frac{1+\phi_y}{1+\zeta}. \quad (88)$$

Conditions [A](#) and [C](#) together boil down then to

$$\phi_y > \frac{1-k}{1-\mu} (1+\zeta) - 1 \quad \text{and} \quad \phi_\pi < \frac{1-k}{1-\mu} \quad (89)$$

or

$$\phi_y < \frac{1-k}{1-\mu} (1+\zeta) - 1 \quad \text{and} \quad \phi_\pi > \frac{1-k}{1-\mu}. \quad (90)$$

Set $\phi_y^* = \frac{1-k}{1-\mu} (1 + \zeta) - 1$. The following proposition summarizes the results above:

Proposition 1. *For $\phi_y > \phi_y^*$, purely expectational shocks cause effects associated with supply shocks when $\phi_\pi > \frac{1+\phi_y}{1+\zeta}$, whereas they cause effects associated with demand shocks when $\phi_\pi < \frac{1-k}{1-\mu}$.*

For $\phi_y < \phi_y^$, purely expectational shocks cause effects associated with supply shocks when $\phi_\pi < \frac{1+\phi_y}{1+\zeta}$, whereas they cause effects associated with demand shocks when $\phi_\pi > \frac{1-k}{1-\mu}$.*

Note that, since $\frac{1-k}{1-\mu} < 1$, it might well be that $\phi_y^* < 0$. In that case the the imposed constraint $\phi_y \geq 0$ binds and only the first part of Proposition 1 is relevant.

In the special case in which $\phi_y = \phi_y^*$, positive purely expectational shocks increase output and employment, however they have no effect on inflation. In case $\phi_\pi = \frac{1-k}{1-\mu}$, positive purely expectational shocks have no effect on output and are inflationary. The case in which $\phi_\pi = \frac{1+\phi_y}{1+\zeta}$ is undefined.

Last, in the two remaining cases, namely when either $\phi_y > \phi_y^*$ and $\frac{1-k}{1-\mu} < \phi_\pi < \frac{1+\phi_y}{1+\zeta}$ or $\phi_y < \phi_y^*$ and $\frac{1+\phi_y}{1+\zeta} < \phi_\pi < \frac{1-k}{1-\mu}$, condition C is met but A is violated. Then positive purely expectational shocks lower output and employment and they raise inflation.

A special case. Consider the case in which $\sigma_u^2 \rightarrow \infty$. Since then $\theta \rightarrow 1$ and $k \rightarrow \mu$ this corresponds to the case discussed in the main text which eliminates the role of the parameters of the agents' learning problem from Proposition 1.

This case implies that $\phi_y^* \rightarrow \zeta$, hence Proposition 1 becomes

Proposition 2 (a special case). *In the case of $\sigma_u^2 \rightarrow \infty$,*

- *for $\phi_y > \zeta$, purely expectational shocks cause effects associated with supply shocks when $\phi_\pi > \frac{1+\phi_y}{1+\zeta}$, whereas they cause effects associated with demand shocks when $\phi_\pi < 1$.*
- *for $\phi_y < \zeta$, purely expectational shocks cause effects associated with supply shocks when $\phi_\pi < \frac{1+\phi_y}{1+\zeta}$, whereas they cause effects associated with demand shocks when $\phi_\pi > 1$.*

For the cases not considered in Proposition 2, check the analysis above.

B.2 Productivity shocks

Suppose that a permanent productivity shock, ϵ_t , hits the economy. Then the impulse responses of output, employment, and inflation are given, respectively, by

$$\frac{dy_{t+s}}{d\epsilon_t} = 1 - (1-k)^s (1-\mu) \xi_1 \quad (91)$$

$$\frac{dn_{t+s}}{d\epsilon_t} = \xi_1 \left(\frac{dE_{t+s}^p}{d\epsilon_t} - \frac{da_{t+s}}{d\epsilon_t} \right) \quad (92)$$

$$\frac{d\pi_{t+s}}{d\epsilon_t} = (1-k)^s [(1+\phi_y) \xi_1 (1-\mu) - (1-k)], \quad (93)$$

where $s \geq 0$.

It follows then from (91) - (93) that a positive permanent productivity shock raises output, lowers employment, and raises inflation when

$$\xi_1 < \frac{1}{(1-\mu)} \quad (D)$$

$$\xi_1 > \frac{1-k}{(1-\mu)(1+\phi_y)} \quad (E)$$

$$\xi_1 > 0. \quad (A)$$

D follows from the fact that $\frac{1}{1-\mu}$ is the minimum value $\frac{1}{(1-k)^s(1-\mu)}$ takes. A second remark is that E implies A.

Condition D requires

$$\phi_\pi > \max \left\{ \frac{1+\phi_y}{1+\zeta}, \frac{\mu + \phi_y + (1-\mu)k(1-\theta)}{\mu + \zeta} \right\} \quad (94)$$

or

$$\phi_\pi < \min \left\{ \frac{1+\phi_y}{1+\zeta}, \frac{\mu + \phi_y + (1-\mu)k(1-\theta)}{\mu + \zeta} \right\}. \quad (95)$$

Condition E requires

$$\phi_y > \frac{1-k}{1-\mu}(1+\zeta) - 1 \quad \text{and} \quad \phi_\pi > \frac{1+\phi_y}{1+\zeta} \quad (96)$$

or

$$\phi_y < \frac{1-k}{1-\mu}(1+\zeta) - 1 \quad \text{and} \quad \phi_\pi < \frac{1+\phi_y}{1+\zeta}. \quad (97)$$

Conditions [D](#) and [E](#) together require

$$\phi_y > \frac{1-k}{1-\mu}(1+\zeta) - 1 \quad \text{and} \quad \phi_\pi > \frac{\mu + \phi_y + (1-\mu)k(1-\theta)}{\mu + \zeta} \quad (98)$$

or

$$\phi_y < \frac{1-k}{1-\mu}(1+\zeta) - 1 \quad \text{and} \quad \phi_\pi < \frac{\mu + \phi_y + (1-\mu)k(1-\theta)}{\mu + \zeta}. \quad (99)$$

Positive permanent productivity shocks raise output and they lower employment and inflation when

$$\xi_1 < \frac{1}{(1-\mu)} \quad (D)$$

$$\xi_1 < \frac{1-k}{(1-\mu)(1+\phi_y)} \quad (F)$$

$$\xi_1 > 0. \quad (A)$$

Observe that [F](#) implies [D](#).

Condition [F](#) requires

$$\phi_y > \frac{1-k}{1-\mu}(1+\zeta) - 1 \quad \text{and} \quad \phi_\pi < \frac{1+\phi_y}{1+\zeta} \quad (100)$$

or

$$\phi_y < \frac{1-k}{1-\mu}(1+\zeta) - 1 \quad \text{and} \quad \phi_\pi > \frac{1+\phi_y}{1+\zeta}. \quad (101)$$

Together [E](#) and [A](#) (for [A](#) see (85)-(86)) imply

$$\phi_y > \frac{1-k}{1-\mu} (1+\zeta) - 1 \quad \text{and} \quad \phi_\pi < \frac{1-k}{1-\mu} \quad (102)$$

or

$$\phi_y < \frac{1-k}{1-\mu} (1+\zeta) - 1 \quad \text{and} \quad \phi_\pi > \frac{1-k}{1-\mu}. \quad (103)$$

Like above, set $\phi_y^* = \frac{1-k}{1-\mu} (1+\zeta) - 1$. The following proposition summarizes the results above:

Proposition 3. *For $\phi_y > \phi_y^*$, positive permanent productivity shocks raise output and inflation and they lower employment when $\phi_\pi > \frac{\mu+\phi_y+(1-\mu)k(1-\theta)}{\mu+\zeta}$, whereas they raise output and they lower inflation and employment when $\phi_\pi < \frac{1-k}{1-\mu}$.*

For $\phi_y < \phi_y^$, positive permanent productivity shocks raise output and inflation and they lower employment when $\phi_\pi < \frac{\mu+\phi_y+(1-\mu)k(1-\theta)}{\mu+\zeta}$, whereas they raise output and they lower inflation and employment when $\phi_\pi > \frac{1-k}{1-\mu}$.*

There are four remaining cases. For either $\phi_y > \phi_y^*$ and $\frac{1+\phi_y}{1+\zeta} < \phi_\pi < \frac{\mu+\phi_y}{\mu+\zeta}$ or $\phi_y < \phi_y^*$ and $\frac{\mu+\phi_y}{\mu+\zeta} < \phi_\pi < \frac{1+\phi_y}{1+\zeta}$ positive permanent productivity shocks raise inflation, lower employment, and they lower output for at least one period.

For either $\phi_y > \phi_y^*$ and $1 < \phi_\pi < \frac{1+\phi_y}{1+\zeta}$ or $\phi_y < \phi_y^*$ and $\frac{1+\phi_y}{1+\zeta} < \phi_\pi < 1$ positive permanent productivity shocks raise output and employment and they lower inflation.

The special case revisited. Consider the case in which $\sigma_u^2 \rightarrow \infty$. Since then $\theta \rightarrow 1$ and $k \rightarrow \mu$ this corresponds to the case discussed in the main text which eliminates the role of the parameters of the agents' learning problem from Proposition 1.

This case implies that $\phi_y^* \rightarrow \zeta$, hence Proposition 1 becomes

Proposition 4 (a special case). *In the case of $\sigma_u^2 \rightarrow \infty$,*

- *for $\phi_y > \zeta$, positive permanent productivity shocks raise output and inflation and they lower employment when $\phi_\pi > \frac{\mu+\phi_y}{\mu+\zeta}$, whereas they raise output and they lower inflation and employment when $\phi_\pi < 1$.*
- *for $\phi_y < \zeta$, positive permanent productivity shocks raise output and inflation and they lower employment when $\phi_\pi < \frac{\mu+\phi_y}{\mu+\zeta}$, whereas they raise output and they lower inflation and employment when $\phi_\pi > 1$.*

For the cases not considered in Proposition 3, check the analysis above.

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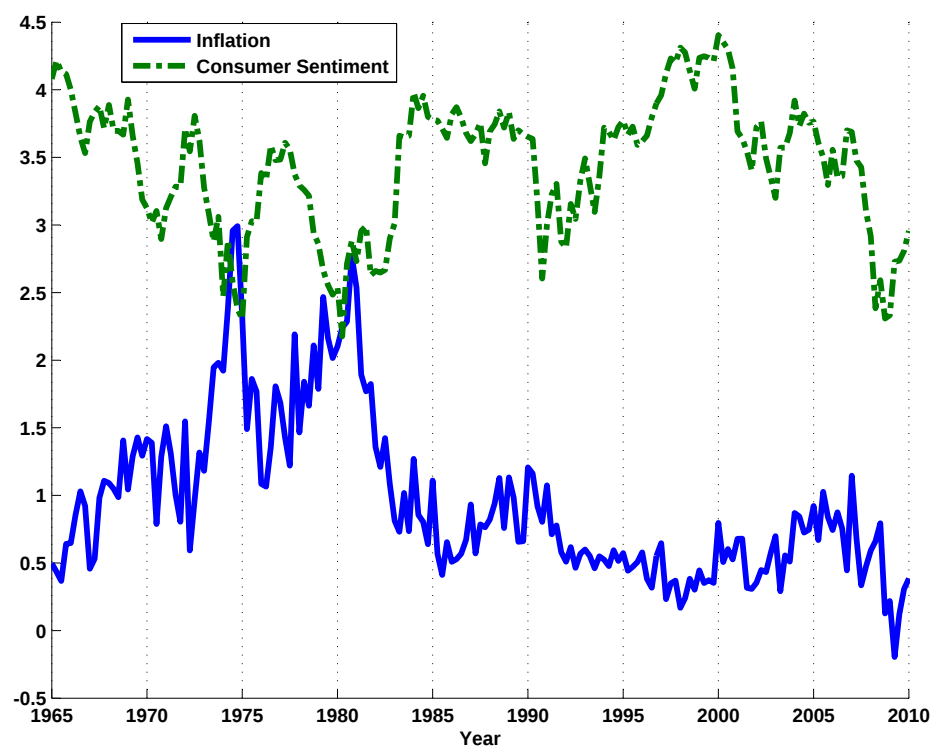


Figure 1: Percent Changes in GDP Deflator and Consumer Sentiment: 1965:1-2010:1 (US quarterly)

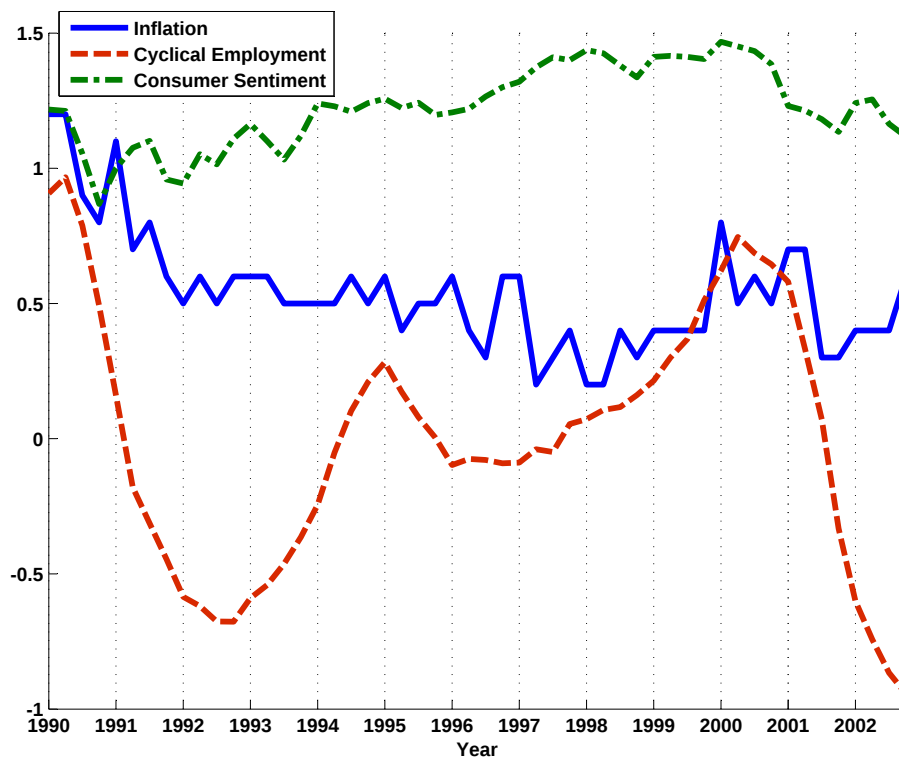


Figure 2: Percent Changes in GDP Deflator, Cyclical Employment and Consumer Sentiment: 1990:1-2002:4 (US quarterly)

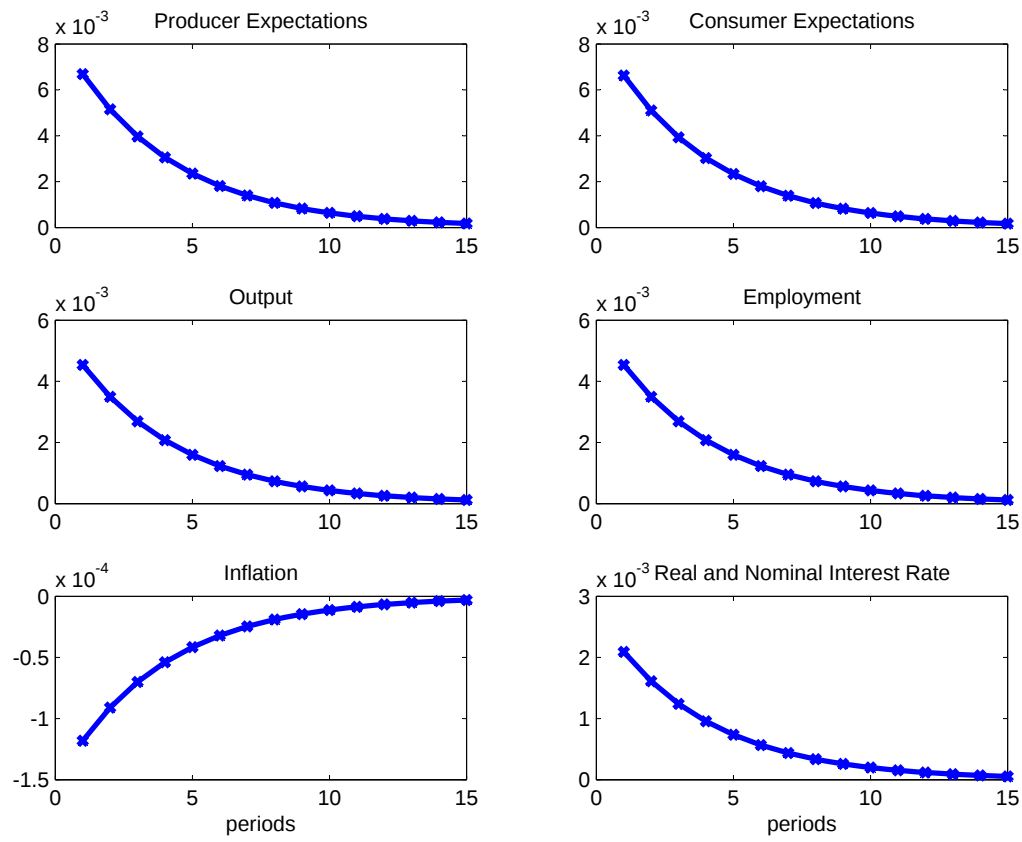


Figure 3: Impulse responses to a positive purely expectational shock for $\phi_y = 0.5$

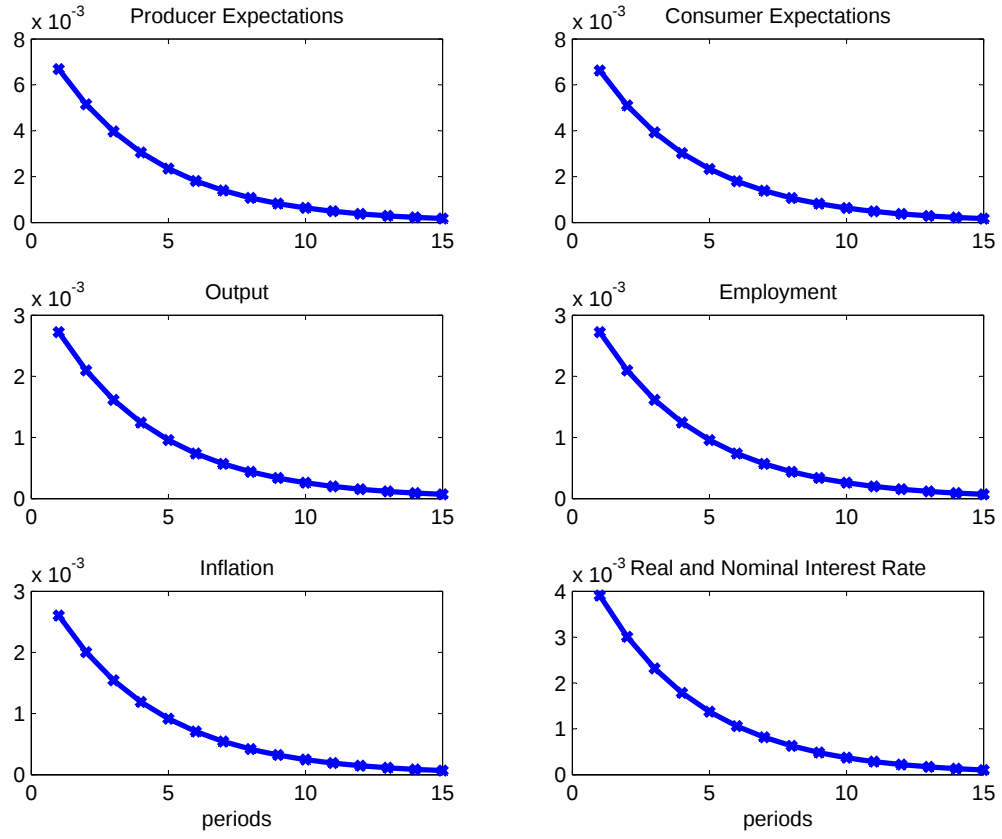


Figure 4: Impulse responses to a positive purely expectational shock for $\phi_y = 0$

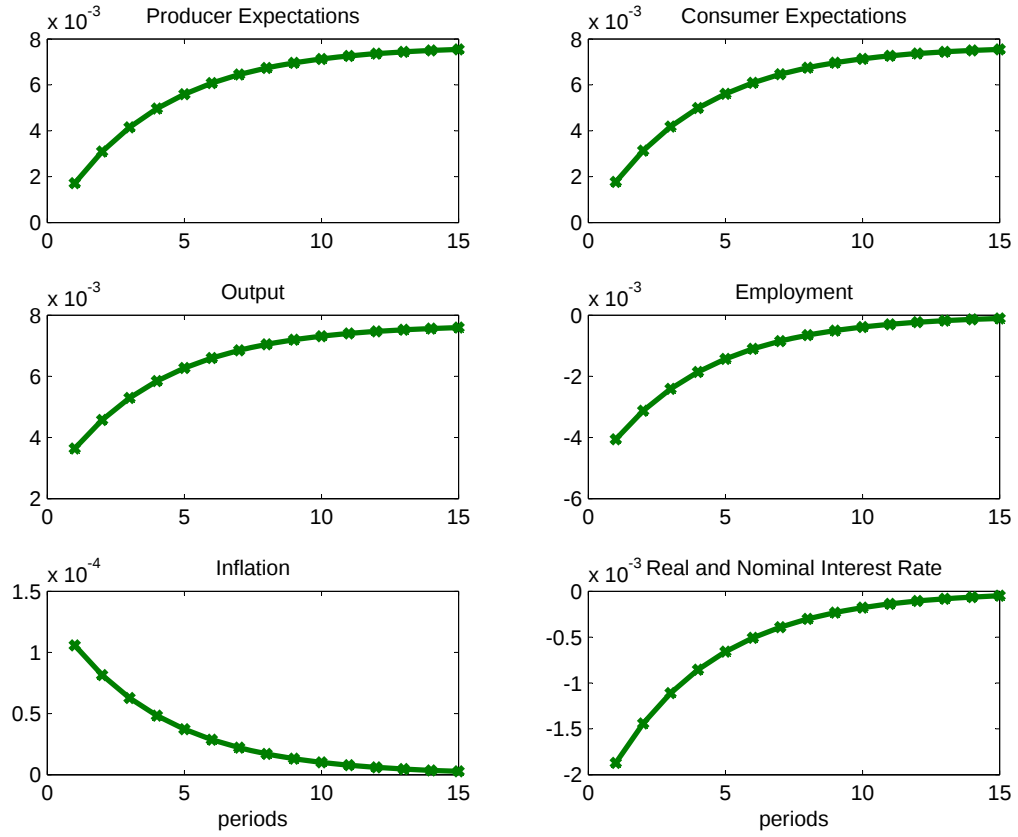


Figure 5: Impulse responses to a positive permanent productivity shock for $\phi_y = 0.5$

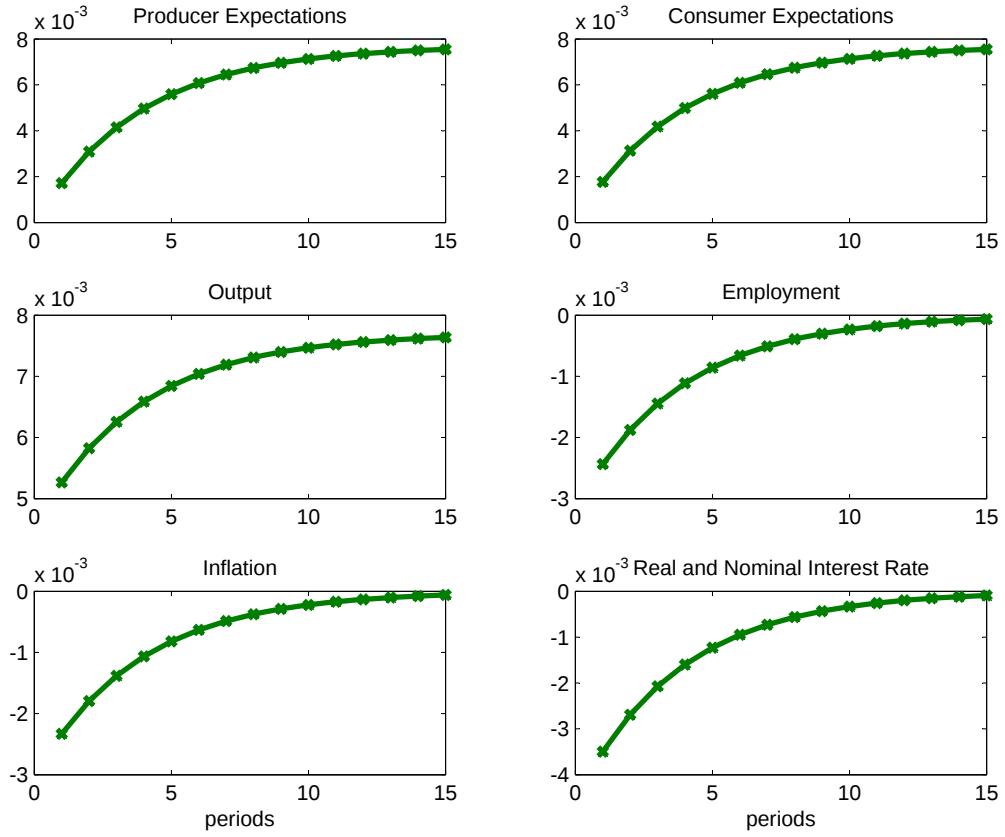


Figure 6: Impulse responses to a positive permanent productivity shock for $\phi_y = 0$

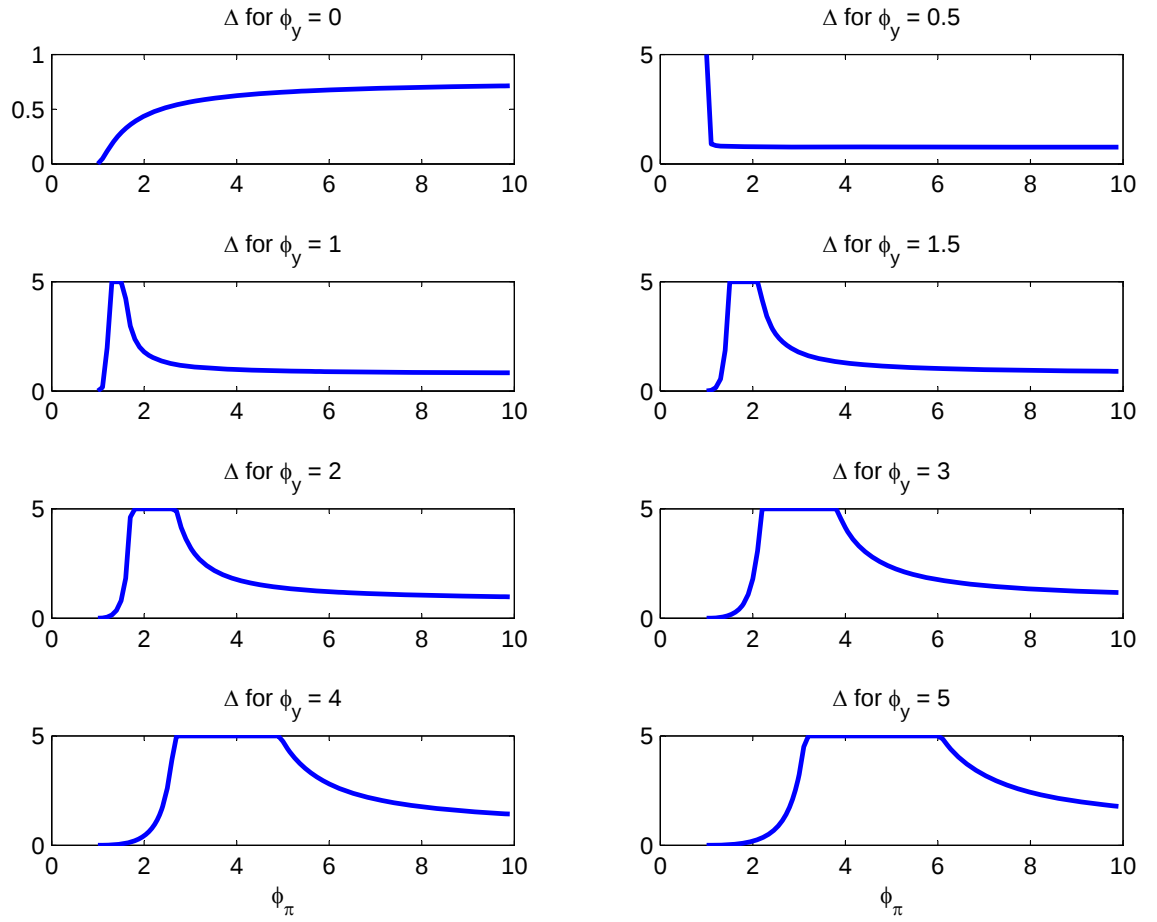


Figure 7: Welfare difference in consumption terms in response to changes in ϕ_π

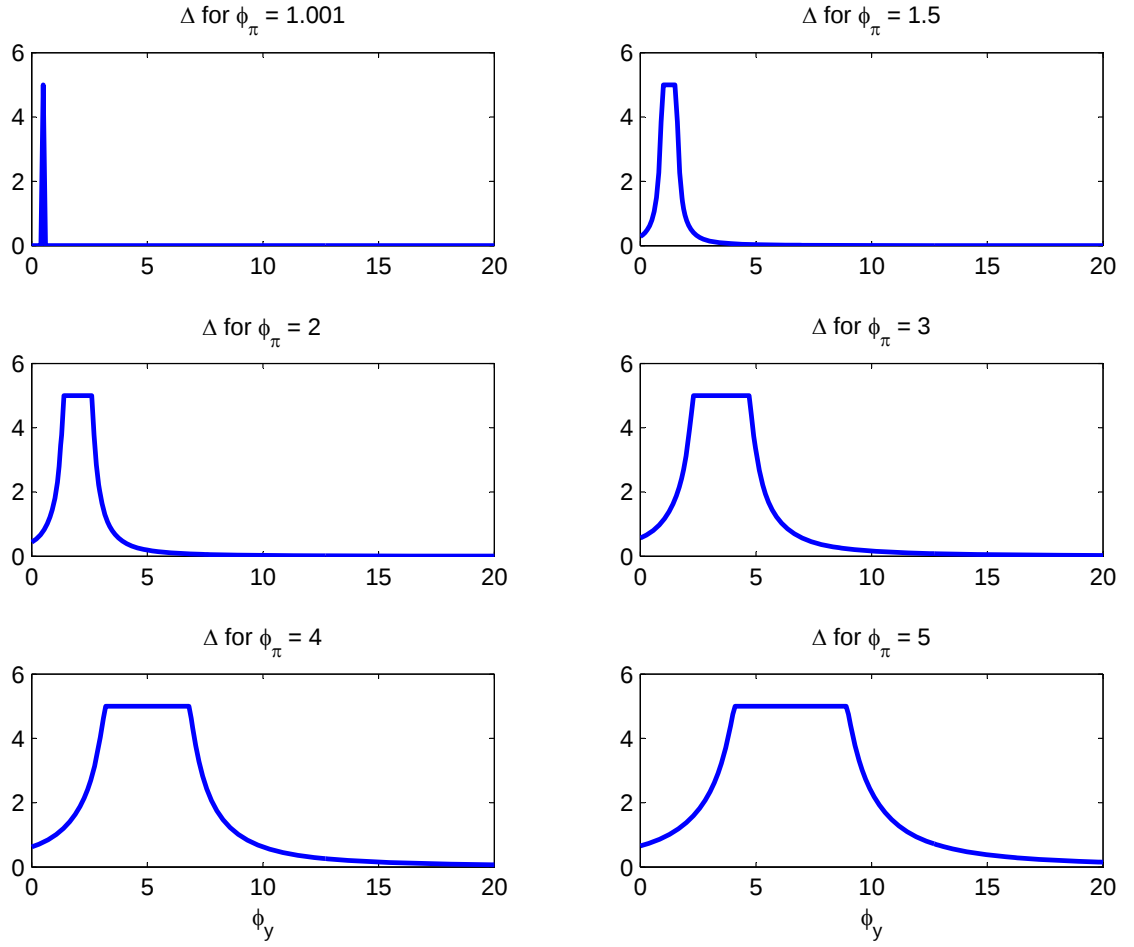


Figure 8: Welfare difference in consumption terms in response to changes in ϕ_y